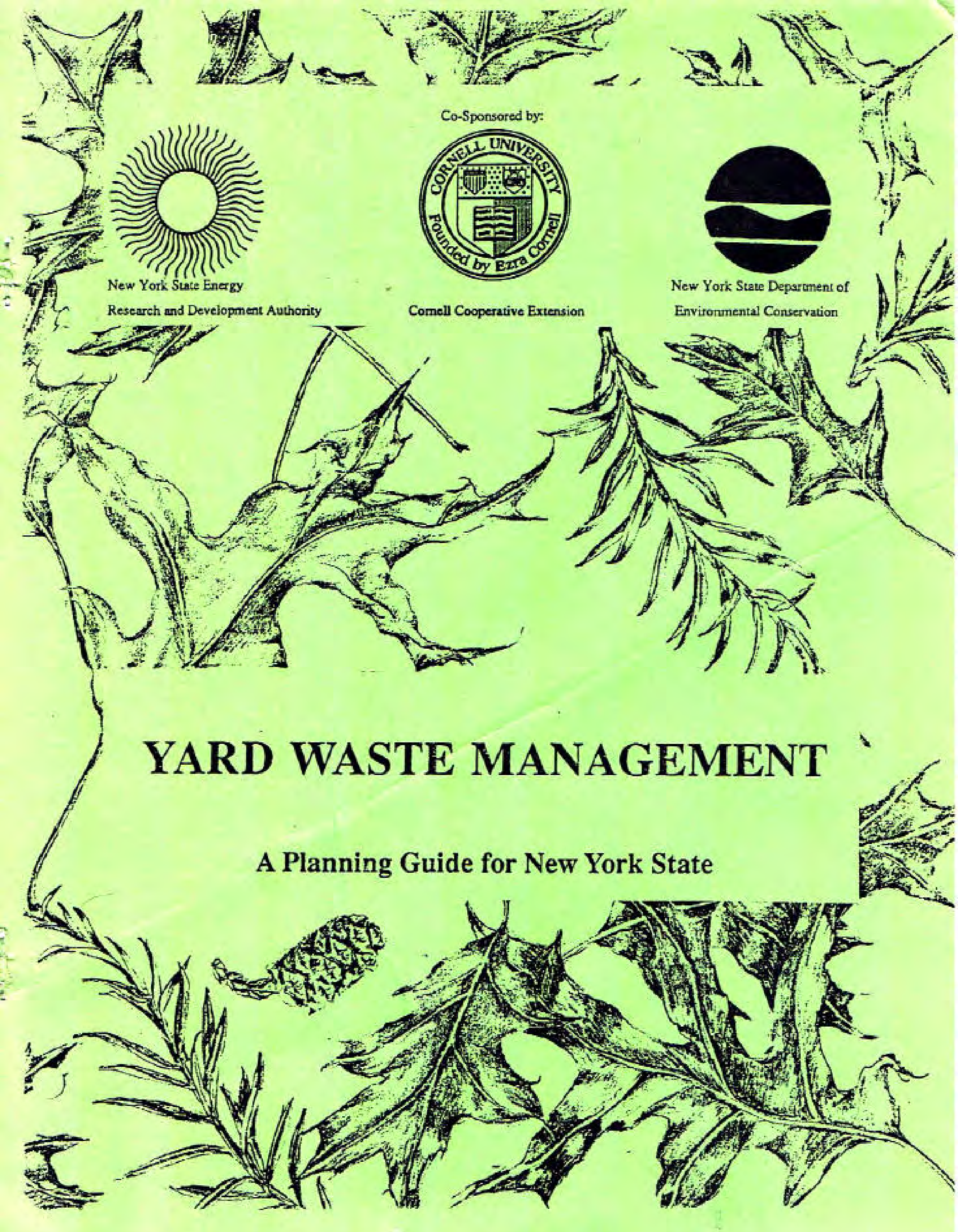

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YARD WASTE MANAGEMENT

A Planning Guide for New York State

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YARD WASTE MANAGEMENT

A Planning Guide for New York State

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YARD WASTE MANAGEMENT

A Planning Guide for New York State

I. MANAGING YARD WASTE: AN INTRODUCTION

Recycling and composting have emerged as attractive alternatives to traditional waste disposal techniques. Among the range of recycling possibilities, yard waste composting and chipping stand out as being both low in cost and easy to manage. Yard waste includes leaves, brush, grass clippings and other organic materials. It can be chipped into a mulch or fuel or made into a finished compost that can be sold or given away. Such recycled yard waste products can be used in place of purchased peat, topsoil, mulches or other soil amendments.

The costs and benefits of chipping and composting versus landfilling or incineration will vary in different communities. Alternative disposal capacity, land availability, and the existing waste collection and management system will all influence the economics of composting. To help in assessing the trade-offs, communities should consider collection costs (including hauling distances), processing costs

and the opportunity to utilize existing equipment or land.

Composting and chipping are practical options for communities in need of a rapid solution to manage a significant portion of their solid waste stream. Since a great deal of yard waste is already collected separately, it is relatively easy to divert to a yard waste management site. The basic equipment, such as front-end loaders and chipping machines, may already be owned by the local public works department. And the skills needed to manage a composting or chipping facility are not overly complicated. This guide provides all of the essentials a public works official needs to know.

With these economic and practical advantages, yard waste recycling should be strongly considered as part of a comprehensive waste management strategy. After thoroughly evaluating their options, many municipalities are finding that chipping and composting are the most economical and environmentally acceptable methods of disposing of large quantities of yard waste.

The development of a successful municipal yard waste management program requires careful planning. This guide outlines the major considerations of municipal yard waste management, and provides the information needed to design an effective program. A yard waste management program may require a year or more to plan, procure a site, obtain permits, and finally implement, so be sure to begin the process well in advance. Figure 1 outlines the major tasks in planning and developing a facility. A more detailed outline of the "Steps in Starting a Yard Waste Management Project" is provided in Appendix A. Information and guidance on specific topics are provided in the sections below:

- Options for recycling yard waste;
- Yard waste management scenarios;
- Chipping brush and woody wastes;
- Composting process;
- Composting methods;
- Chipping woody wastes;
- Weight and volume estimates of yard waste;
- Collection;
- Site selection;
- New York State DEC Solid Waste Permit Requirements;
- Personnel;
- Marketing;
- Financing a municipal composting facility; and
- Public acceptance and community involvement.

II. OPTIONS FOR RECYCLING YARD WASTE

Yard waste chipping and composting reduces the mass and volume of waste, while also converting that waste into useful products. Compost and mulch from chips are in great demand by home gardeners, institutions with landscaping requirements, and commercial nurseries. Chips can also be marketed as a fuel, although transportation distances to wood-fueled boilers make this uneconomical in some areas. If demand for these products is seasonal or prices fluctuate, both chips and compost are stabilized and much easier to store than unprocessed yard waste.

A. Home Composting

Home composting takes the waste disposal problem and stops it at its source. It reduces the amount of yard waste that municipalities need to collect as part of their municipal composting programs. By avoiding municipal collection, processing, and distribution costs, home

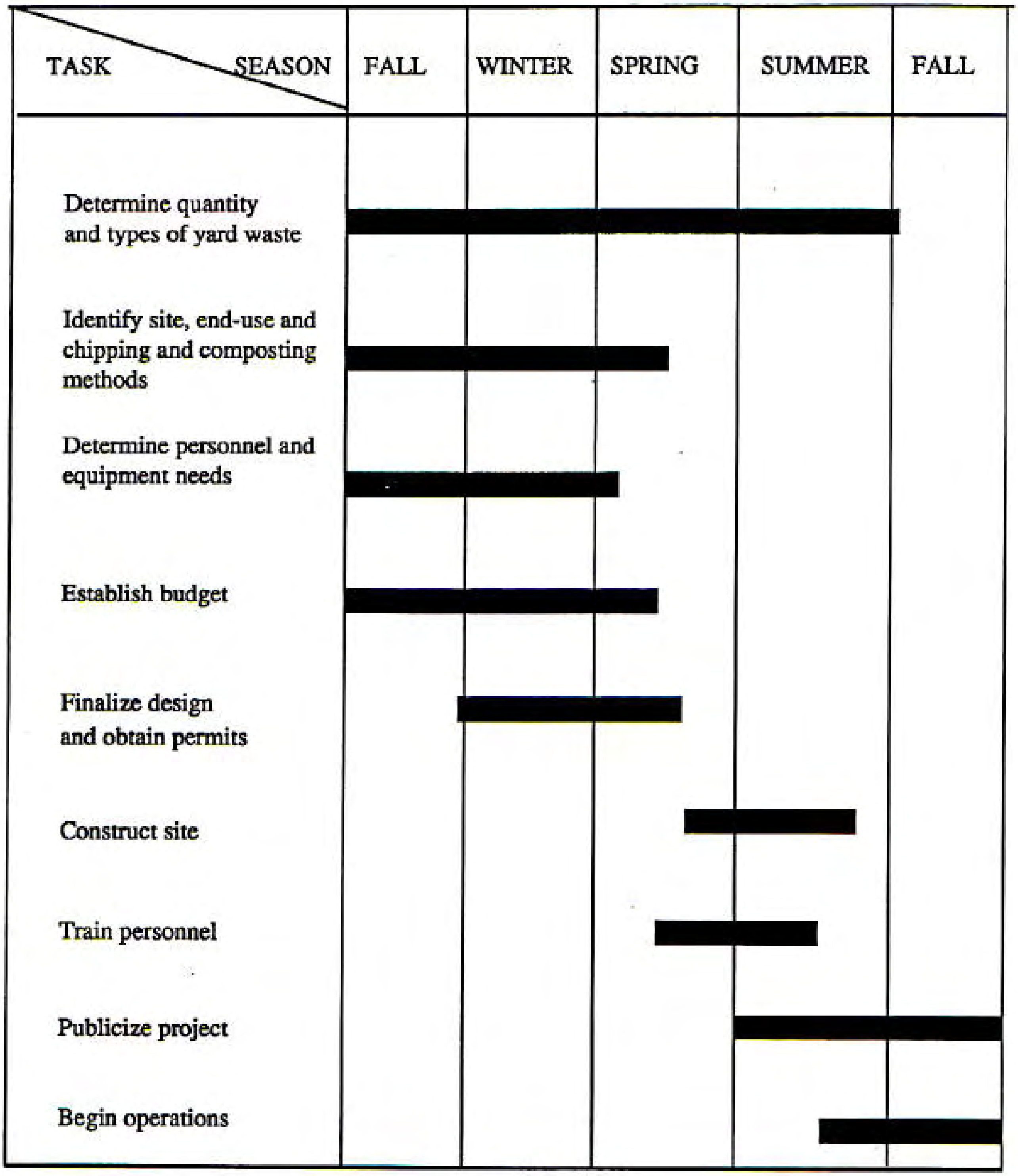


Figure 1. Planning Schedule

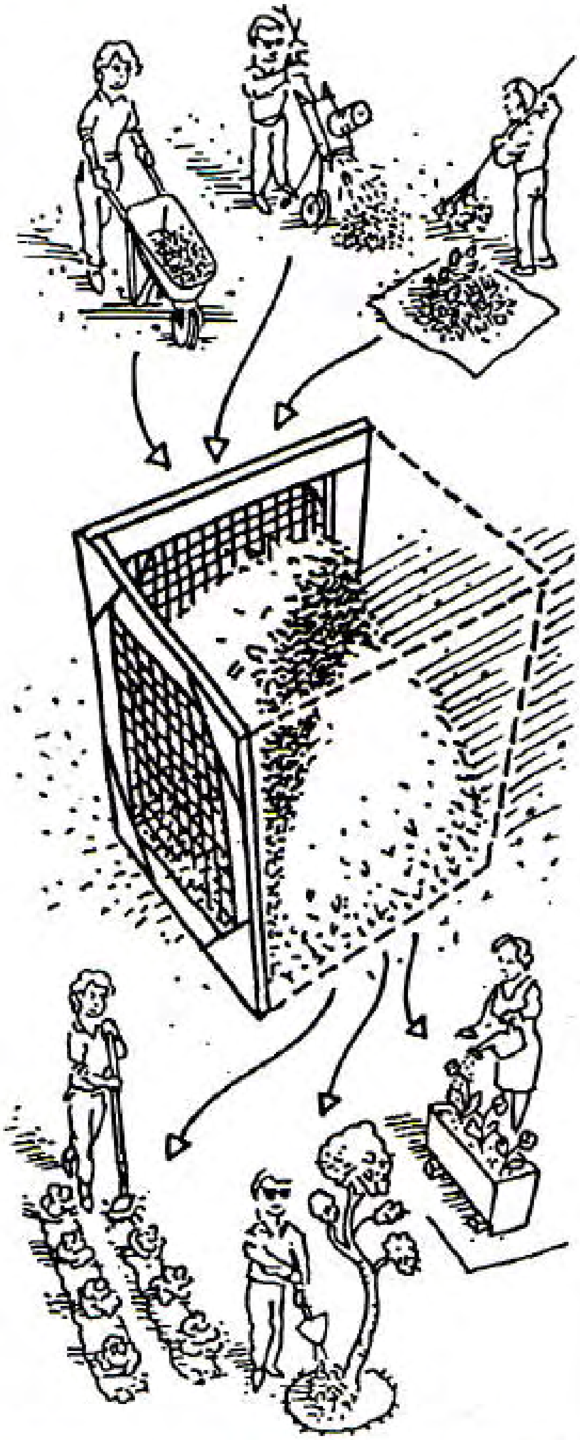
composting represents the lowest cost-management alternative.

However, home and municipal yard waste composting should be seen as complementary activities. Home composting helps to familiarize the public with the concepts behind a large-scale municipal program. Because home composting diverts at least some yard waste and provides hands-on experience with the composting process, a home composting education program is an important component of an overall yard waste management strategy.

Some materials that can be easily recycled at home create challenges for a large municipal facility. Grass clippings, which are best left on lawns where they recycle their nutrients, can generate odors if not carefully managed at a large-scale facility. Food wastes are another example: easy to compost at home, but difficult to separate, collect, and process at a municipal facility. Effective promotion of home composting options can significantly increase the recycling of these materials.

Yard maintenance contractors can help encourage home composting. In areas where tipping fees are high or disposal sites distant, some contractors offer clients reduced fees if the yard waste is managed at the client's site. In this arrangement, either the contractor or the homeowner can manage the backyard compost pile.

Sometimes local ordinances



COMPOST FLOW CHART

prohibit or discourage home composting, and these may need to be amended. Backyard composting, when properly managed, does not pose public health problems. Different techniques for composting on large or small lots, and even in apartment buildings, can ensure that home composting takes place in a safe, acceptable way.

Cornell Cooperative Extension has a variety of resources, including instructional brochures and compost demonstration sites, which can form the core of a home composting education program. Appendix W contains a list of home composting educational resources. For more information contact your county Cornell Cooperative Extension office.

B. Municipal Composting

Many local governments now favor community-wide composting for managing yard wastes that are source separated. From an environmental perspective, composting not only reduces the problems associated with landfills and incinerators, but the finished compost adds beneficial humus and nutrients to soil. Thus, composting is one waste management solution that actually can improve the environment.

The potential negative impacts of yard waste composting on air, land and water should be minimal if a composting facility is properly sited and managed. Excess runoff poses a threat because biodegradable wastes running into surface waters can deplete the oxygen supply for fish; however, careful attention to drainage patterns can help control this problem. Odors also can present a problem whenever insufficient air diffuses through the compost piles, but with adequate monitoring and management this problem should rarely occur. Management strategies that address runoff and odor are discussed in Appendix C.

C. Municipal Chipping

While many yard waste materials can be composted, either at individual homes or at community-wide facilities, large woody materials are usually best processed separately. Chipping and grinding equipment can turn tree trunks and branches into chips, which are suitable as mulch or as fuel. Larger pieces can be sawn and split for firewood. Because these materials can be marketed immediately, a wood chipping facility takes up relatively little space.

Some types of wood chipping equipment can also process wood from construction and demolition projects. Although the contaminants in this waste stream may make it unsuitable as a mulch, demolition wood waste has high energy value for use as a fuel. While markets for wood chip fuel are currently scarce in New York State, that could change as energy prices rise.

Overall, the environmental and economic benefits of yard waste recycling can be significant. A successful yard waste management program can ultimately serve as the cornerstone of a comprehensive recycling plan in many municipalities.

III. YARD WASTE MANAGEMENT SCENARIOS

As local officials and citizens consider their options for yard waste management, several different levels of technology are possible. The choice among these levels will depend on the types and quantities of yard waste in the waste stream, and local availability of land, labor, capital, time, and various other resources needed to make a project happen. The resources that seem most often critical in these decisions are: 1) the amount and kinds of yard waste to be managed; 2) the availability of land for a site; and 3) the time available to complete the composting process (which is inversely correlated with the amount of land available).

To help local governments make informed choices, we have grouped these options into a limited number of scenarios. Although it is certainly possible for a community to mix and match technology across different scenarios, the groupings described below are typical of the types of facilities now in use. For each scenario, the scale and complexity of the yard waste management operation will probably be roughly similar to that of the yard waste collection system.

These scenarios are brief. More detailed descriptions of composting technologies are found in the composting methods chapter. Case study examples from each of these scenario types also will be published and available separately. Each case study will include a project description, economic analysis, and other detailed information, and will be available from Cornell Cooperative Extension or the New York State Department of Environmental Conservation.

Low-tech: slow-rate, mixed yard waste.

Yard Waste:	Leaves, brush, and woody waste (no grass).
Equipment:	Front-end loader and wood chipper or occasional use of a tub grinder.
Volume:	Small to moderate (< 3000 cubic yards/year).
Time:	Eighteen months to two years for compost, less for mulch or chips.
Area:	Typically 1 - 2 acres, processing 2000 cubic yards of yard waste per acre of site annually.
Examples:	Homer, Madison Co., Scarsdale, Pittsford.

This option requires a minimum investment in personnel and equipment, but will require considerable acreage because most yard waste remains on the site for approximately two years. Equipment such as front-end loaders and wood chippers are borrowed as necessary from other public works activities or rotated to serve a number of low-tech sites. This type of operation does not require its own full-time staff, but might be located at a public works barn, a landfill or recycling center, or some other facility where staff are available when needed. Several nurseries, farmers, and landscape contractors are currently operating small facilities for their local communities in a privatized arrangement.

On-site processing of yard waste is minimal. Woody wastes and brush can be stockpiled until a chipper or grinder is available, which can then generate chips for immediate use as fuel or mulch. Large woody wastes and stumps may be processed a few times a year in a mobile tub grinder, or are hauled to a private wood waste processing facility. Leaves are moistened if necessary and piled in windrows approximately 10 feet high and 20 feet wide. These windrows are turned two to four times a year with a front-end loader. Some of the chipped brush might be combined with leaves to produce a coarse textured compost. The compost is ready for distribution in about two years.

It is rarely worthwhile for small communities to expend the effort needed to make money marketing the compost product. Finished compost and mulch are usually used on public works projects or given away to residents. Chips are generated in relatively small quantities on an irregular basis, so if they are sold as fuel their market value is nominal.

Communities report operating costs for low-tech facilities range from $5 to $25 a ton. Land and capital equipment costs are often not included in these reported costs, and can make a significant difference if purchase is necessary. Note that reported costs for each scenario are for compost processing only, and do not include yard waste collection costs.

Intensive low-tech: medium-rate, mixed yard waste.

Yard Waste:	Leaves, brush, and woody waste (possibly small quantities of grass clippings).
Equipment:	Dedicated front-end loader and wood chipper, occasional use of a tub grinder, compost shredder, and/or specialized windrow turner.
Volume:	Moderate (3000 to 20,000 cubic yards/year).
Time:	Approximately one year for compost, less for mulch or chips.
Area:	Typically 1 to 5 acres, processing approximately 4000 cubic yards of yard waste per acre of site annually.
Examples:	New Hartford, Croton on Hudson, Brookhaven.

This is currently the most common scenario for medium sized yard waste management facilities in New York State. Dedicated equipment at the site allows year-round processing of leaves and woody wastes, for more rapid turn around of materials and more efficient use of land. At least one part-time staff person is required, with additional staff for larger sites and during heavy collection periods in the spring and fall. Most of the facilities that currently fit this scenario are publicly managed and operated, although some privatized facilities exist.

Woody wastes and brush are chipped as they arrive and marketed as fuel or mulch. Large woody wastes and stumps may be processed a few times a year in a mobile tub grinder, or hauled to a private wood waste processing facility. Leaves will probably receive additional water before being piled in windrows 6 to 10 feet high and 12 to 20 feet wide. Smaller windrows may be combined into larger windrows during the winter, and they are turned at least monthly throughout the year. If grass clippings are handled at the site, sufficient leaves or wood chips must be stockpiled so they can be thoroughly mixed with incoming clippings. Partially composted leaves are often used for this purpose. Occasional use of a specialized windrow turning machine will help break up clumps of leaves and grass clippings and improve the final product. Additional shredding may be required at the end of the composting period, depending on the marketing strategy.

Distribution options for the finished products include giveaway programs, use on public works projects, or marketing to other potential users. Screened and processed material can be effectively marketed on the local level, particularly to bulk users such as landscape contractors and nurseries.

Communities report operating costs range from $10 to $30 a ton, with land costs rarely included in these figures.

Intermediate-tech: high -rate, mixed yard waste.

Yard Waste:	Leaves, grass clippings, brush, and woody waste.
Equipment:	Dedicated front-end loader, tub grinder or stationary hammermill, compost shredder and/or screen, and specialized windrow turner.
Volume:	Moderate to large (> 10,000 cubic yards/year).
Time:	Four to eight months for compost, less for mulch or chips.
Area:	Typically 5 to 20 acres, processing approximately 6000 cubic yards of yard waste per acre of site annually.
Examples:	Islip, Schenectady, Krehers (privatized).

Communities that generate large quantities of yard waste or have a limited area for processing may find this scenario attractive. Specialized equipment produces a high quality product quickly, and allows a municipality to manage grass clippings as well as leaves, brush, and woody wastes. This scenario is more equipment intensive than the low-tech options, so that a facility must process more material in order to justify the capital expense. Several full-time staff to operate the facility will also be required. The year-round operation and economies of scale in this scenario make it attractive to privatized operators, who may be able to serve several different communities in a cost-effective manner.

A tub grinder is the most common piece of equipment for processing large quantities of wood waste into chips, but stationary conveyor-fed hammermills may also be appropriate at very large facilities. The quantities of chips generated at this scale of operation may be enough to interest purchasers of chipped wood for fuel. A tub grinder may also be used for preliminary mixing of leaves and grass clippings, which will then be piled in windrows for composting. Additional mixing and shredding is accomplished by the specialized windrow turning machines, which are used to turn the windrows weekly or even daily during the initial stages if grass clippings are included. Finished compost is run through a shredder or screen to produce a very marketable product. Compost sale prices range from $2 to $5 a cubic yard wholesale to distributors, to as high as $20 a cubic yard retail near urban areas.

Processing costs for this scale of operation are likely to be in the range of $20 to $30 a ton, not including the cost of land. This assumes a relatively large facility which can use the equipment efficiently. If the chips or compost are sold commercially, some of that sale price may help subsidize the processing costs, although much of the income will go into the marketing operation.

High-tech: high -rate, mixed yard waste and sludge.

Yard Waste:	Leaves, grass clippings, brush, and woody waste. Also may include municipal sewage sludge.
Equipment:	Aeration system and blowers, dedicated front-end loader, tub grinder or hammermill, compost shredder and/or screen.
Volume:	Small to large (basic technology independent of scale).
Time:	Two to four months for compost.
Area:	Typically 1 to 10 acres, processing over 10,000 cubic yards of sludge and yard waste per acre of site annually.
Examples:	Tompkins Cty., Manchester/Shortsville, Minoa, Yorktown Heights.

In recent years many municipalities have seen increasing interest in composting municipal sludge. With landfills closing and the upcoming ban on ocean dumping of sludge, this interest is likely to rise. Sludge composting requires the addition of a high carbon bulking amendment, and woodchips have long been popular for this purpose. Leaves can also serve a similar purpose. Because of pathogen concerns with sewage sludge, greater process control is needed to insure a safe final product. Dedicated equipment is usually required for similar reasons. Facilities range in size from very small (< 300 dry tons per year of sludge) on up to handling the sludge from cities the size of Philadelphia.

Sludge is typically mixed with chipped wood or leaves in a ratio of 1 part sludge to 3 parts yard waste (by volume), or about 1 dry ton of sludge to 12 cubic yards of yard waste. If grass clippings are included, they will substitute for the sludge because of their high moisture content. These materials are typically blended with a front-end loader, although more thorough mixing will be accomplished by augers or other specialized mixing equipment. The mixture is then either piled in windrows, over perforated pipes for forced aeration, or conveyed into one of several types of in-vessel composting systems. Temperature feedback should be used to control the blowers, to keep the compost temperatures in the optimum range. After three to four weeks, the compost can be moved off from the aerated piles to a curing location for at least another month. At the end of the curing process, screens can be used to produce a finer quality product.

Sludge compost can be marketed to most of the same groups as yard waste compost, depending on the contaminant level of the sludge. The DEC regulations specify quality requirements for different marketing options.

Blowers, electricity, piping, and temperature feedback control systems make this a more expensive option than turned windrows. Outdoor forced aeration systems typically cost $20 to $50 per ton of waste. In-vessel systems, with buildings and containment structures, are more expensive, from $40 to as high as $150 per ton of waste. These costs are on an "as is" weight basis, and would be higher on a dry ton basis depending on moisture content.

These high-tech systems require a more sophisticated level of design and management. A wide range of systems are available, with consultants or equipment vendors designing a facility for a particular situation. Selection of a system will depend on the types and quantities of work, siting restraints, cost and reliability.

How to Select a Scenario to Suit your Community

For some communities, a quick reading of the above scenarios results in one obvious candidate for local adaptation. Other communities will have a wider range of choices, and this section will help with making the right choice.

The five parameters listed at the beginning of each scenario are those that we consider central to the choice. The type and volume of yard waste will in most cases determine the choice: a community with over 50,000 cubic yards of yard waste to process is unlikely to be satisfied with a low-tech, slow-rate system, and similarly the intermediate and high-tech options will rarely make sense for a small rural village that does not generate any sludge.

Smaller communities may be driven to the high-tech options if land is a severe constraint, or if they want to handle more challenging materials such as food waste or sludge. On the other hand, a large governmental unit may opt for a decentralized composting program - small dispersed satellite sites will cut down on transportation costs of both yard waste and compost, and may be easier to find space for than a single, very large facility.

In evaluating these trade-offs, remember that economies of scale for processing equipment need to be balanced against site development costs and transportation costs. Small sites generally require less equipment, are exempt from most regulations, and often operate fine with minimal management. The bigger and more sophisticated facilities, while they can process a large quantity of yard waste in minimal time, can also be a considerable challenge to operate efficiently. With those factors in mind, try to select a system that will best serve your community's needs.

IV. CHIPPING BRUSH AND WOODY WASTES

Of all the materials in the solid waste stream, woody yard wastes are perhaps the easiest to recycle. A variety of shredding and grinding machines will transform woody brush and branches into chips, which are immediately marketable or can be easily stored. Furthermore, markets for the chip products, either as a mulch or as a fuel, are more stable than the markets for many other recyclable materials.

Woody waste materials come in a wide range of shapes and sizes, and their recycling options are equally diverse. Small branches and twigs of about 1/2" diameter or less are easily shredded and can be combined with other yard waste for composting. Larger branches, even when chipped, will decompose slowly and may be easier to manage and market separately. Large branches and tree trunks have value as firewood if they can be sawn into fireplace-sized lengths. Stumps are perhaps the most difficult material, requiring large, expensive and high maintenance machinery for processing.

There are three general types of chipping equipment that might be appropriate for a yard waste management facility: mobile chippers, tub grinders, and stationary hammermills. These equipment choices are discussed briefly below, with additional information available in Appendices D and E.

For small quantities of woody waste, a small mobile chipper such as is used by utility companies and arborists may be most cost-effective. A mobile unit could be used at a permanent yard waste management facility, or it could make periodic rounds through neighborhoods to chip brush, possibly even leaving the chips at the curb for homeowners to pick up for their use. Many public works departments already own such a unit, so it may be possible for a yard waste management facility to share existing equipment. The primary limitations of these smaller units are their lower throughput rates and their limited capacity for large pieces of woody waste.

Tub grinders consist of a large diameter rotating tub that feeds a hammermill. These units are semi-portable and can usually handle woody materials up to railroad tie size or larger. Stationary hammermills differ from tub grinders in that they are fed by conveyor belts. They are available in a variety of capacities to handle almost any amount and type of waste.

Tub grinders and stationary hammermills can process a large volume of material, and either can be connected to screens and magnetic separators to produce a high quality end product. Both require a considerable capital investment, and maintenance on the hammers can be both frequent and expensive. Stumps, plastic bags, dirt, and other contaminants in the incoming waste will increase these maintenance requirements. Specially hardened steel on the critical wear surfaces can significantly extend the service time of the hammers.

The high capital and maintenance costs of tub grinders and hammermills may not be justifiable for smaller communities. In some areas private contractors provide wood processing services on a contract basis. Wood waste may be transferred to a private facility, or a mobile mill or grinder may come to the public facility on an as-needed basis. Since woody materials are fairly easy to stockpile, scheduling of such services can be more flexible than with composting.

The market outlets for wood chips have somewhat different requirements. Chip size, moisture and age can be managed to suit the users of the chips. Mulch users such as landscapers and parks are primarily concerned about size, shape and color. Most large chipping and grinding equipment can produce several different chip sizes, usually by changing a replaceable screen that prevents larger pieces from leaving the grinding chamber. A second stage of screening also may be used to separate the smallest chips and dirt from blending with compost or soil. If mulch users prefer a uniform brown product, aging the chips for a few weeks will turn any green foliage brown.

If the chips are going to be marketed as a fuel or as a carbon source for sludge composting, they need to be kept as dry as possible. Covered storage areas may be required if the chips must be stockpiled. When storing large quantities of wood chips, caution should be exercised to help prevent fires (see Fact Sheet # 9, Health and Safety Precautions in Cornell's "Operators Guide to Yard Waste Management."

V. THE COMPOSTING PROCESS

Composting involves the microbiological conversion of raw organic waste into stable, soil enriching humus. A basic understanding of the compost process can help produce a high quality product, while preventing many common operating problems. The microorganisms that do the work in composting have a few basic requirements that need to be met. Air, water, nutrients, surface area, temperature, and pH are all important factors in the composting process. Table 1 displays the optimal composting conditions for yard waste.

Table 1. Optimal Composting Conditions

Oxygen	>5%
Moisture	~40-60%
Carbon : Nitrogen	30 : 1
Temperature	90-140° F (32 - 60°C)
pH	6-8

A. Air

Yard waste composting is an aerobic process, which means it occurs in the presence of oxygen. The air we breathe is about 21 percent oxygen. Compost organisms can survive with as little as 5 percent oxygen. However, if the oxygen level falls below 5 percent, the process can become anaerobic (i.e., without oxygen). As anaerobic organisms decompose wastes, they produce methane, which is an odorless gas, and hydrogen sulfide, which smells like rotten eggs. Because odor complaints are the most common problem at yard waste composting sites, maintaining an adequate oxygen supply is critical.

Air can be supplied by either passive or active means. If pile size remains moderate, fresh air can passively diffuse in from the outside of the pile, accelerated by forces of natural convection caused by high temperatures within the windrow. Leaf compost piles 6 to 8 feet tall and 10 to 15 feet wide will get most of their air in this manner. Materials that are less porous or decompose more quickly, such as a mixture of grass clippings and leaves, must be placed in smaller piles or oxygen will be depleted. Additional oxygen can be provided mechanically by turning the compost with a front-end loader or a specialized compost turner. In the high-tech composting systems, oxygen is provided by blowers distributing air to the pile via perforated pipes.

The human nose is the ideal sensor of inadequate oxygen levels in a compost pile. For more quantitative measurements, suppliers of oxygen monitoring equipment are listed in Appendix E.

B. Water

Active microorganisms need a moist environment. A moisture content between 40 and 60 percent is ideal. When conditions are too wet, water will fill the pores required for air diffusion, and anaerobic conditions result. If conditions are too dry, the decomposition rate will slow down. For leaves, the "squeeze" test is an easy way to gauge moisture content. The leaves should feel damp to the touch, with only a drop or two of water expelled when tightly squeezed in the hand.

For more quantitative measurements, weigh a sample (about 1/2 of a cup) wet, then oven dry (~ 220°F or 104°C for approximately 8 hours) and weigh it again. The difference (water weight) divided by the wet weight (remember to subtract the container weight) is the moisture content.

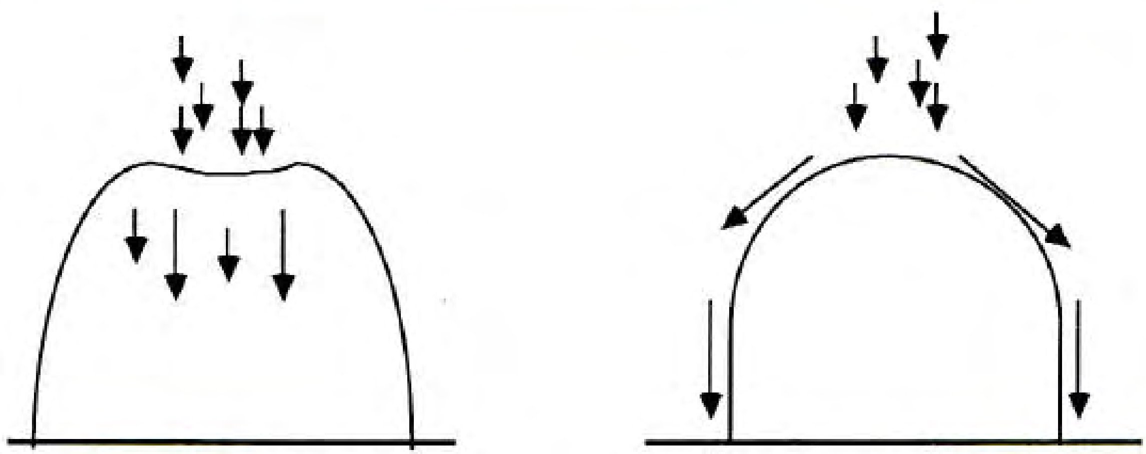


Figure 2. Windrow Shapes for Maximum and Minimum Water Absorption

The shape of a compost pile will influence moisture content. Scooping out the top of the pile to create a concave shape will maximize water absorption, so that rainfall can help replenish the moisture that is lost from the pile as steam. However, if the pile is overly saturated, anaerobic odors and leachate will be produced. Therefore, in prolonged wet conditions, the pile should be shaped to form a peak that will minimize absorption by shedding water. Figure 2 illustrates both of these shapes.

Water can be added to the compost pile in various ways. Hosing yard waste as the windrow is turned or turning it on a rainy day can help get water into the pile. Overhead sprinklers on a concave shaped pile also work well. By applying water slowly, it is more likely to infiltrate the pile, rather than running off the surface. Another method uses a drilled pipe as an injection probe, delivering pressurized water from a water truck to the center of the pile where it can be readily absorbed. As a rule of thumb, dry leaves initially need about 20 gallons of water for every cubic yard of leaves.

C. Carbon to Nitrogen Ratio

When combining organic materials to make compost, the concept of carbon to nitrogen ratio (C:N) is critical. The microorganisms in compost require carbon for energy and nitrogen for protein synthesis as they oxidize organic matter. The proportion of these two elements, ideal for microbial decomposition, averages 30 parts carbon to 1 part nitrogen by weight.

If the carbon to nitrogen ratio deviates greatly from this ratio, the microbial system will suffer. When there is little nitrogen, the microbial population will not grow to its optimum size, and composting will slow down. In contrast, too much nitrogen allows rapid microbial growth and accelerates decomposition, but this can create serious odor problems as oxygen is depleted and anaerobic conditions occur. In addition, some of this excess nitrogen will be given off as ammonia gas, which generates odors and allows valuable nitrogen to escape. Therefore, materials with a high nitrogen content, such as grass clippings, require more careful management, with adequate aeration or frequent turning, as well as thorough blending with a high carbon waste.

Table 2. Carbon to Nitrogen Ratios

High Nitrogen Materials		C:N
Sewage Sludge:	Activated	6:1
	Digested	16:1
Humus		10:1
Food Wastes		15:1
Grass Clippings		19:1
Cow Manure*		20:1
Horse Manure*		25:1
High Carbon Materials		**C:N**
Fruit Wastes		35:1
Foliage		40-80:1
Corn Stalks		60:1
Straw		80:1
Bark		100-130:1
Paper		150-200:1
Wood and Sawdust		300-700:1

*Livestock bedded with high carbon materials will increase C:N ratio

Waste materials can be blended to improve the carbon-nitrogen balance and hasten decomposition. For example, leaves typically have a ratio of 40 to 80 units of carbon to 1 unit of nitrogen. Although leaves will compost slowly by themselves, they can benefit from additional nitrogen. Mixing leaves with a high nitrogen waste, such as grass clippings, manure, or nitrogen fertilizer will accelerate the decomposition process. Adding one part grass clippings to three parts leaves, or one to two pounds of nitrogen fertilizer (e.g., ammonium nitrate or urea) to a cubic yard of leaves, will balance these nutrients and help composting proceed in the shortest possible time. Table 2 presents estimates of the C:N ratios of various compostable materials. These values can vary. For example, brown grass clippings from a poorly kept lawn will have far less nitrogen content than lush green clippings from an abundantly fertilized lawn. Likewise, the leaves from different types of trees vary in their C:N balance.

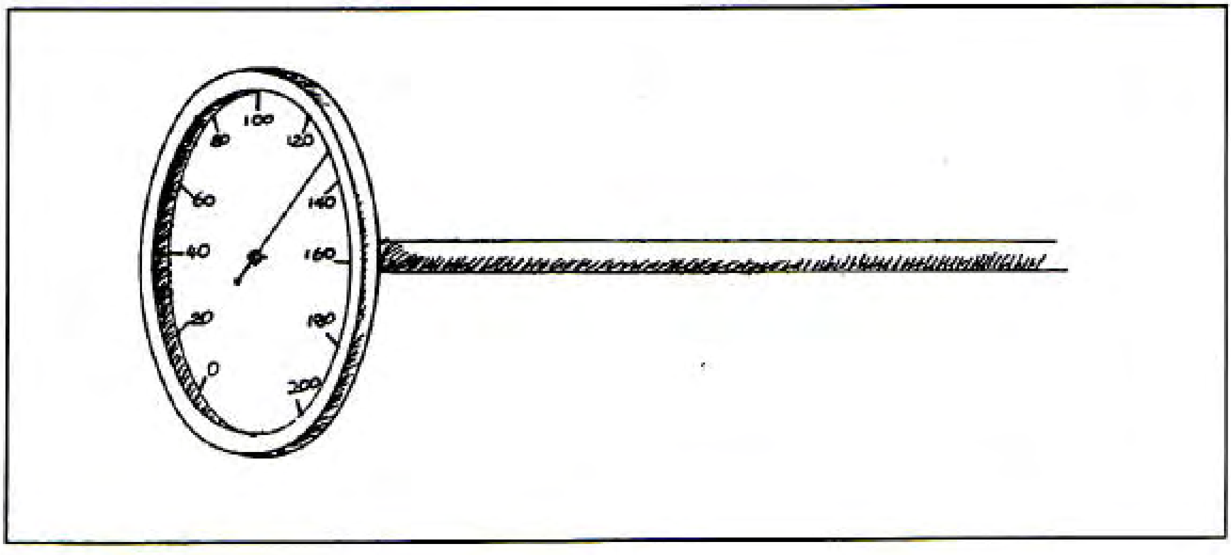
D. Surface Area

Surface area also is important in the compost process. Small particles, with more surface area per unit of volume, make nutrients and energy more available to microorganisms. Shredding yard waste exposes more surfaces to microbial activity, thus accelerating decomposition. Because shredding restricts air flow at the same time that it increases the oxygen demand, finely shredded yard waste needs to be turned more frequently to prevent anaerobic conditions. Some facilities have found that running leaves through a shredder will reduce the time required to produce finished compost from 18 months to 9 months. Shredding can occur as part of other processing operations. For example, some vacuum leaf collection trucks shred very effectively as they collect. Windrow turning machines also partially shred the waste as they turn and aerate the piles.

E. Temperature

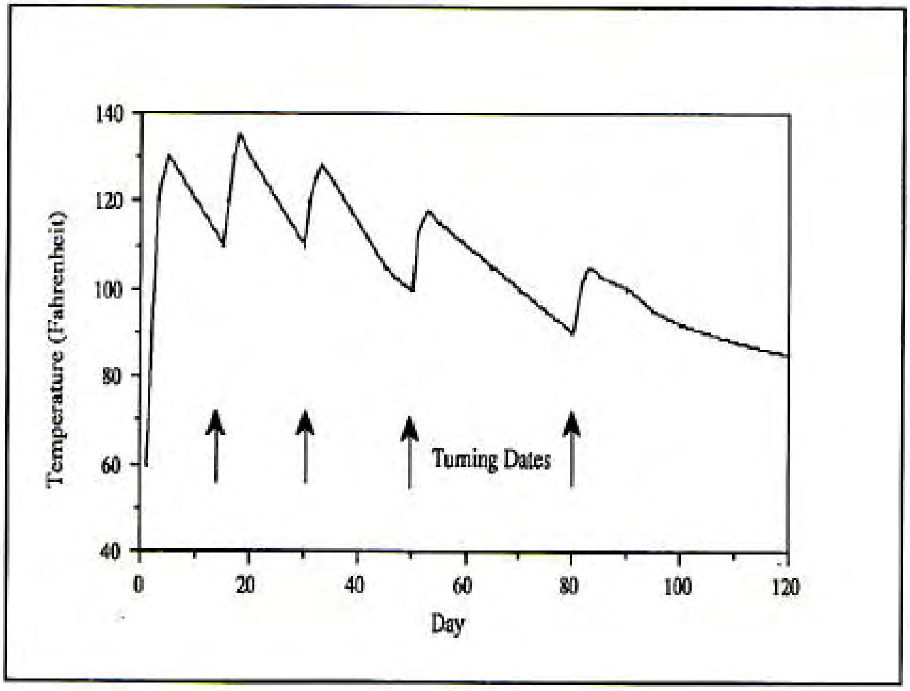
As organisms decompose waste, they generate heat. Decomposition is most rapid when the temperature is between 90°F and 140°F (32°C and 60°C). Below 90°F (32°C), the process slows considerably, while above 140°F (60°C) most microorganisms cannot survive. Compost pile temperature depends on how the heat produced by microorganisms is offset by the heat lost through aeration or surface cooling. During periods of extremely cold weather, piles may need to be larger than usual to minimize surface losses. When composting high nitrogen wastes, like grass clippings in the summer, smaller piles and frequent turnings are needed both to provide oxygen and to release excess heat.

Figure 3 is a graph of typical compost temperatures. After an initial high temperature period (of a few days to several weeks), compost pile temperatures will gradually drop. Turning the compost rejuvenates the oxygen supply and exposes new surfaces to decomposition, causing



temperatures to rise. When the temperature drops below 70°F (21°C), the composting process is nearly complete. However, it is also possible that imbalances of oxygen or moisture are causing the pile to cool. If the compost is moist, and turning does not cause temperatures to rise, the compost is probably finished and ready to market.

Temperature monitoring is crucial for managing the compost process. Thermometers with a three to four foot probe are available from a number of sources listed in Appendix E. By turning the compost whenever temperatures get above or below the optimum range, high quality compost will be produced in the shortest possible time. A windrow temperature data sheet is provided in Appendix B.



F. pH

Another factor that can be useful in diagnosing and correcting certain operating problems is the pH of compost. pH provides an indicator of the acidity or alkalinity of the composting material, and is measured on a scale from 0 (very acidic) to 14 (very basic), with 7 being neutral. Decomposition occurs most efficiently between pH 6 and pH 8, which are the normal values for yard waste compost.

During the initial stages of decomposition, organic acids are formed that are normally immediately consumed by microorganisms. Without enough oxygen in the compost pile, these acids will not be converted as quickly. Excess acidity may lower the pH below 6, and in turn slow down decomposition. Extra aeration will usually solve this problem, but in extreme cases it may be helpful to add lime or another neutralizing agent and raise the pH back into its optimum range. However, it is also important to avoid overly high alkalinity (> pH 8.0), which can cause the release of unpleasant smelling ammonia gas.

The pH of compost also can be a factor in marketing the finished product. Final pH above 8.0 can damage or kill acid-loving plants like azaleas or blueberries, especially if used in large quantities. Compost product testing is described in Chapter XIV on marketing, and large quantities. Compost product testing is described in Section XIII on marketing, and samples can be tested by any commercial laboratory. Testing pH is very simple, and also can be done on-site with a soil pH testing kit.

Minor variations from the optimum composting process will usually not cause significant problems. The goal is to promote rapid composting without creating anaerobic conditions, which result from either too much moisture, excess nitrogen, or inadequate turning and aeration. More detail about troubleshooting potential problems is provided in Appendix C.

VI. COMPOSTABLE WASTES

This guidebook focuses on yard wastes: leaves, grass clippings, and woody debris. Leaves are the most popular yard waste to compost because they are least problematic. They account for most of the yard waste generated in the fall, and in many cases are already separated from other solid waste. Leaves usually take a year or more to completely decompose, unless they are turned frequently or mixed with a material with high nitrogen content.

While leaves are perhaps the easiest organic waste to compost, they are only a part of the total yard waste stream. Yard wastes such as grass clippings, shrub prunings and garden wastes are the predominant yard wastes disposed of from April through October. Large limbs and stumps are an almost year-round component of the yard waste stream, with large quantities generated occasionally by major storm events.

Fresh grass clippings require special attention in a compost system. Because grass clippings are relatively high in nitrogen they begin to decompose almost immediately and can be completely composted in four to six weeks. However, composting grass clippings alone requires frequent turning and thorough mixing to avoid odor problems. Turning may be required as often as twice a day for the first week or two. Blending grass with leaves or chipped brush slows decomposition to a more manageable rate. A 3:1 ratio of leaves to grass seems to work well, although the mixture will still need to be well mixed and turned to minimize odor potential.

In some instances, grass may have residues of chemicals used in lawn maintenance programs. Once absorbed by a plant, the fertilizer or herbicide may take a few weeks or perhaps months to degrade to a relatively harmless state. While significant levels of contamination have not been found in finished compost, this issue continues to be investigated at several yard waste composting facilities in the Northeast.

Brush and wood are high in cellulose and lignins, the tissues that form the woody cell walls. Lignins in particular are very slow to decompose. Even with chipping or shredding, it typically takes several years for woody materials to completely break down, so they should not be mixed with other yard wastes unless a coarse, chunky compost is desired. Instead, most communities consider other market options for chips, such as those described in the section on chipping woody wastes.

A range of other organic waste materials can also be composted. Food processing wastes, manures, and other agricultural wastes are all readily composted, although sometimes different materials need to be combined to balance the carbon and nitrogen levels. Some farmers are making a business of co-composting farm wastes with municipal yard wastes and food processing wastes. Farm composting can provide extra income for the farmer, solve a facility siting problem for the local government, and produce a higher quality compost by combining complementary wastes.

Co-composting yard wastes with mixed municipal refuse or sewage sludge requires a significantly greater level of monitoring and process control. Temperature must be held above 131°F (55°C) for three consecutive days for pathogen control. The presence of toxic contaminants in sludge or solid waste may require leachate control at the compost site and could constrain the eventual use and markets for the compost (i.e., there may be restrictions prohibiting use on food crops). When working with these types of materials, controlling the quality of the inputs is essential if a high quality product is to result.

VII. COMPOSTING METHODS

There are many different methods of composting. Four broad classes of technology are used to compost organic wastes, and each has advantages for different materials in various situations.

A. Leaf Piles

A truly "minimal" technology, leaf piles evolved from traditional leaf dumping long practiced by individuals and communities. The method (if it can be called that) consists of piling leaves twenty feet high or more, and leaving them for a few years. Although this method is simple and can be effective, it does have a number of disadvantages. Huge leaf piles can overheat, and in some cases spontaneous combustion may result. (See Section XI "Health and Safety Precautions") During the first year or two, the center of a large pile will be anaerobic (i.e., oxygen starved) and serious odors are likely to result if it is disturbed. Composting under these conditions is also very slow, so leaves must remain on the site for several years. In addition, leaf piles may be unsightly. Because a managed leaf pile can be difficult to distinguish from a simple leaf dump, it may attract dumping of other waste materials, such as batteries and refrigerators, and therefore be a less acceptable option, in the view of neighboring residents and regulatory agencies.

B. Turned Windrows

A windrow is an elongated pile that can be several hundred feet in length. In the turned windrow method, mixing and aeration are accomplished by mechanically turning the windrow. This is the most common method used for rapid composting of yard wastes, and is the principal focus of this guidebook.

Windrows are usually 6 to 10 feet high, 10 to 20 feet wide, and as long as is appropriate for the site. This size is large enough that the center of the pile will be insulated and composting can continue even when outdoor temperatures are below freezing. Windrows are formed using a front-end loader, and are turned periodically with either a front-end loader or specialized turning equipment to provide adequate aeration and temperature control. Figure 4 illustrates a turned windrow site profile for turning piles using: 1) a front-end loader; 2) a self-propelled windrow turning machine; and 3) a side-mounted windrow turning machine. Appendix D, "Collection and Processing Equipment," provides more detailed information on compost processing equipment and their approximate costs. Processing costs range from $5 to $30 per wet ton, easily competitive with most other disposal options available today.

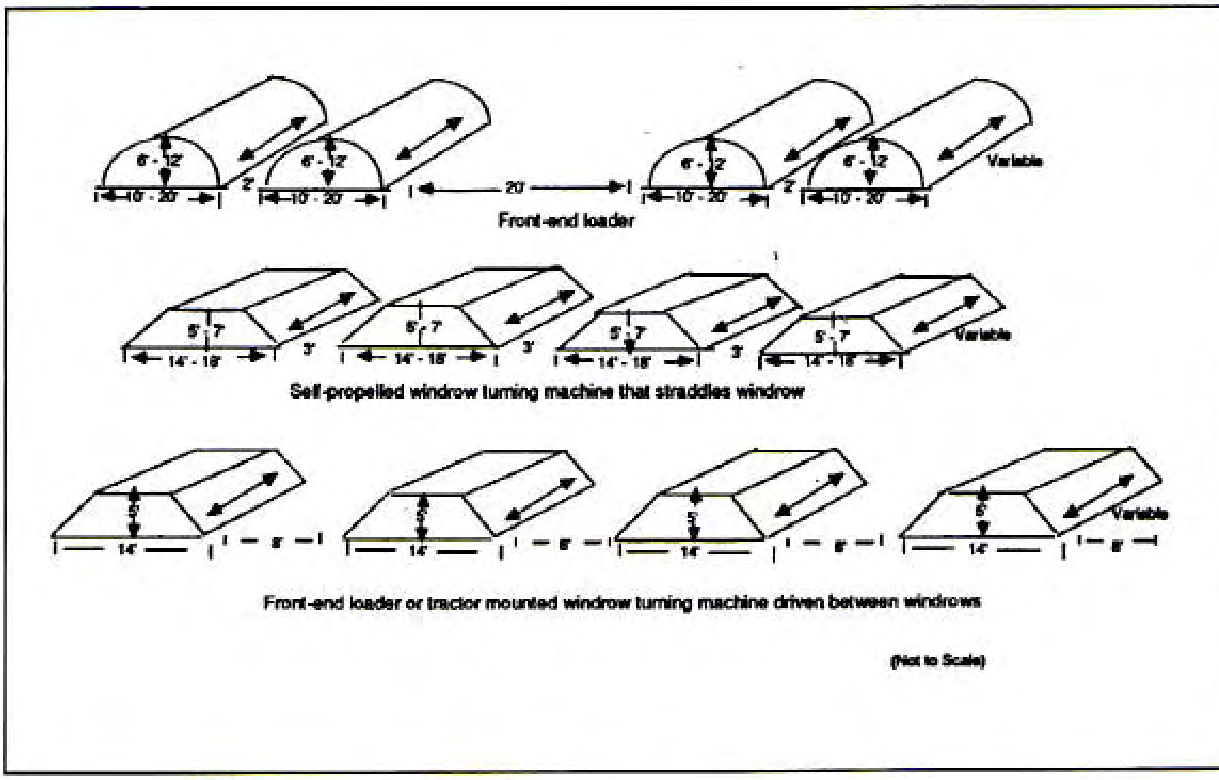


Figure 4. Turned Windrow Site Profile

Frequency of turning offers the best means for controlling the process in windrow composting. Turning mixes material from the surface of the windrow to the center, where it will more rapidly decompose, and also releases heat and steam from the center of the pile. To prevent overheating, windrows should be turned whenever temperatures in the center of the pile approach 140°F (60°C). While turning based on temperature monitoring will usually keep the compost aerobic, oxygen monitoring equipment can also be used to ensure that oxygen levels stay above 5 percent, the level necessary to prevent odor problems. Appendix E provides a list of collection and processing equipment manufacturers and a list of oxygen monitoring equipment manufacturers.

Turning frequency will vary depending on the nature of the raw waste materials and how long they have been composting. Although windrows composed entirely of fresh grass clippings may initially need to be turned twice daily to prevent odors, those made entirely of leaves may only need to be turned once a season. Turning more frequently than necessary never hurts, producing a more uniform, quality compost in less time.

Turning Techniques

Windrow turning is proof that there is a little bit of art in the science of making compost. Equipment operators who understand the principles of the composting process will soon become expert at deciding when and just how to turn the windrows. Important priorities in the turning process are:

- to move materials from the surface to the center of the windrow and vice versa;
- to lift compost and let it cascade into its new location, maximizing porosity and oxygen penetration; and

- to shape the windrow to help control moisture.

Finished compost can be made in as little as three months or as long as two years, depending on the type of waste and ambient temperatures (e.g., winter air temperatures will slow the compost process), as well as turning frequency. Most yard waste facilities currently operating produce a finished product in 12 to 18 months. The composting process may be accelerated by pre-shredding leaves, more frequent turning, or by the addition of nitrogen as described in the carbon to nitrogen ratio section. Such extra efforts to speed up the composting process may be necessary in communities where a large amount of waste needs to be processed on a small site.

Most communities begin a yard waste composting program by composting leaves. Leaves are seasonal, high volume wastes that are relatively easy to collect and compost. An eighteen month cycle is typical for leaves turned every month or two with a front-end loader. Figure 5 illustrates the various steps in the operation of a turned windrow facility. Leaves are collected and brought onto the site during October, November, and early December. As the leaves arrive, they are watered as necessary and piled in windrows. Piles built in the fall will shrink up to 50 percent by January. Adjacent piles can then be turned and combined with a front-end loader, these new piles being turned approximately monthly.

When these windrows are turned the following August, they can be dismantled so as to clear most of the site for incoming leaves in the fall. The nearly finished compost can be placed in large "curing" piles where it will further stabilize. During the last six months it may take to

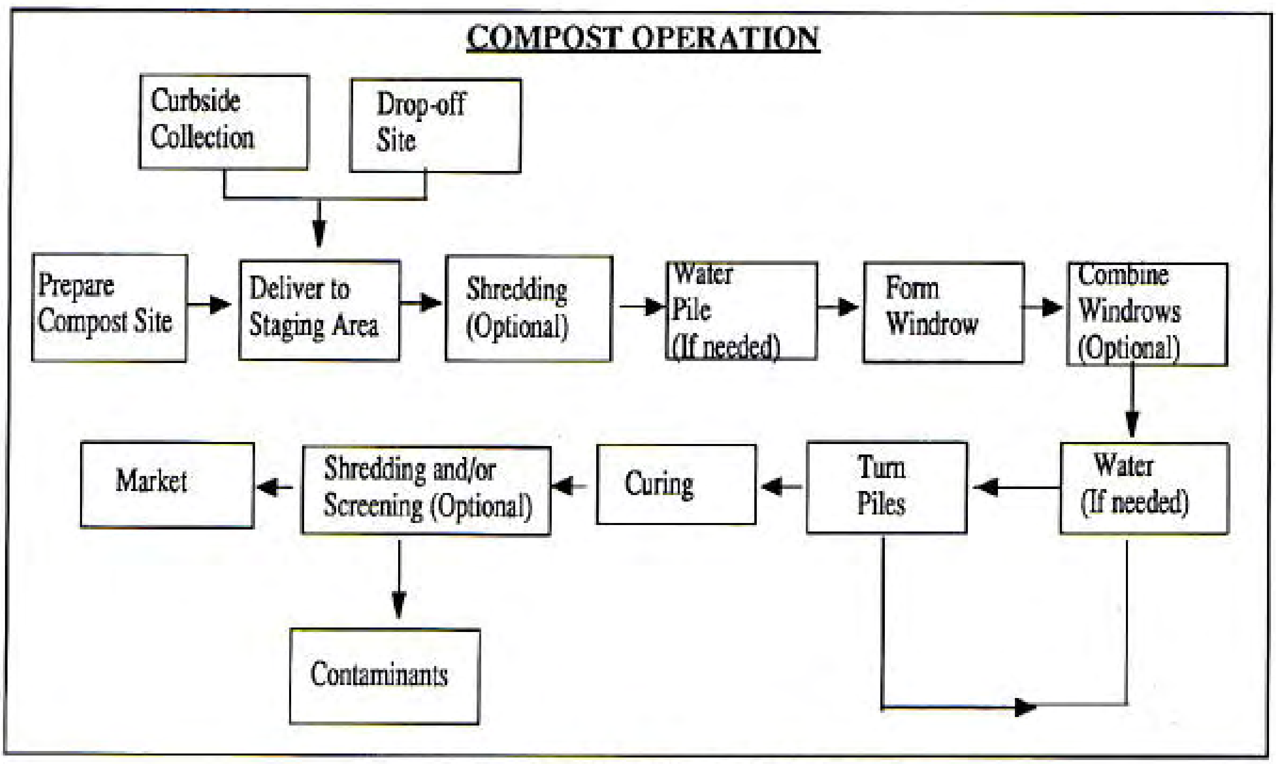


Figure 5. Operations Flow Chart for Leaf Composting

cure, compost is often shredded or screened to produce a finer, more homogeneous product. When the compost has cooled below 70°F (21°C) as described in the temperature section, the compost is ready to market. Finished compost should be ready for distribution in March or April, just in time for spring gardening needs.

C. Forced Aeration

Forced aeration is sometimes known as the aerated static pile method. It follows similar principles as the turned windrow method, except that aeration is accomplished by a network of perforated plastic pipes under the compost pile. A compost pile is built on top of this pipe network, and the pile is not turned until the compost is finished. Air is drawn or blown through the pile by exhaust fans or small blowers. The pipes are positioned in a layer of wood chips to provide a porous foundation. As shown in Figure 6, the piles are often covered in a layer of finished compost to reduce evaporation and ensure that all of the compost reaches adequate temperatures.

Blowers, electricity, and piping make this a more expensive method than turned windrows, so that forced aeration typically costs $20 to $50 per wet ton. Because of the expense, this method is most commonly used for composting sludge, food processing wastes, or fresh grass clippings, where aeration and temperature control are crucial. These wastes usually require the addition of a bulking agent to balance the carbon to nitrogen ratios, absorb moisture, and increase the porosity for aeration. While the standard bulking agents are sawdust and wood chips, yard waste may be a cost-effective substitute in some systems.

For a community considering co-composting yard waste with sludge, a forced aeration system can be an economical way to handle the combined wastes. In areas where land is at a premium and yard waste must be processed in high volumes, this method may be appropriate for

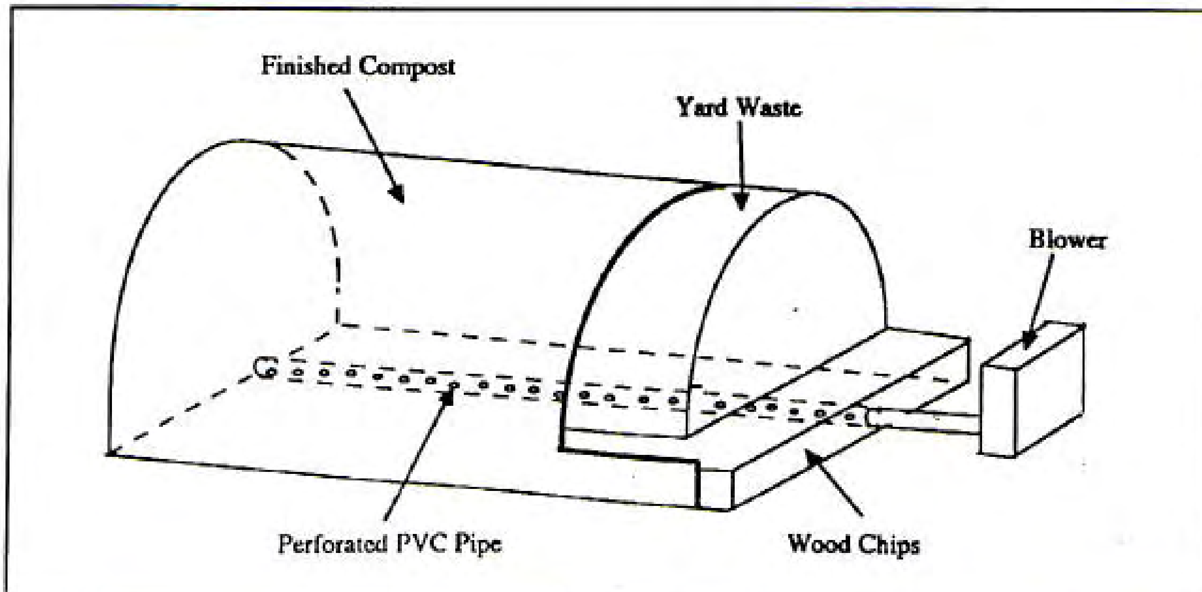


Figure 6. Aerated Static Pile

yard wastes alone.

Blowers or exhaust fans are the critical components of this system, but, as yet, little information is available on sizing them to handle wastes other than sludge-wood chip mixtures. For high-rate composting of sludge mixed with wood chips, the current recommendation suggests a capacity of 350 cubic feet per minute per dry ton of sludge. Air blowing through the compost has two important functions: it supplies oxygen and carries off waste heat. A blower control system which maintains the proper temperature range of 90°F to 140°F (32°C to 60°C) will also supply ample oxygen. Blowers need to be protected from the elements. If no other enclosure is available, they can be mounted on wooden pallets and covered by empty steel drums. Since the amount of aeration required to maintain those temperatures will vary during the compost process, as microbial decomposition slows and ambient temperatures fluctuate, temperature feedback is critical. This feedback can be accomplished either through frequent monitoring and manual setting of equipment timers by thermostatic controls, or by a sophisticated computer control system.

Other equipment needed for the aeration system is relatively simple. Perforated plastic drainage tile is commonly used to distribute the air. This flexible plastic tubing is laid on the ground and wood chips and other waste materials are piled on top. General site requirements are similar to those for turned windrow composting. A windrow layout is commonly used, although the piles can be larger and wide aisles are not required for turning equipment. If the other parameters such as moisture content and carbon to nitrogen ratios are balanced, composting can be completed in a few months.

D. In-vessel Systems

A number of complete indoor composting systems are available commercially. Raw wastes are placed in a large container, often with built-in aeration and mechanical mixing equipment. In-vessel systems offer the advantages of protection from severe weather and potentially complete odor control. Due to high capital, operating, and maintenance costs, these systems are expensive to build and operate, ranging from $40 to $150 per wet ton of wastes. Because of these high costs, in-vessel systems are generally not used to compost separated yard waste. However, they can provide excellent process control for co-composting yard waste with sludge or food processing waste, mixed solid waste, and other difficult to manage materials. The design and operation of in-vessel composting systems is beyond the scope of this guide book. Consultants and equipment vendors can be contacted through advertisements in BioCycle magazine.

VIII. WEIGHT AND VOLUME ESTIMATES OF YARD WASTE

When planning a composting facility the weight and volume of a community's yard waste stream must be estimated. This estimate will help to determine site design and capacity. Unfortunately, most communities have limited information about the composition of their solid waste, and national or even regional averages may not be relevant. The relationship between population and generation rates for yard wastes varies widely according to community characteristics such as population density, number of mature trees, and average lawn size. Table 3 lists the leaf weight and volume estimates for a number of communities in Westchester County. Estimates were made by public works officials and are not necessarily confirmed values.

An initial approach to estimating yard waste would be to compare your community's characteristics with those of a similar community that already has some data. General estimates of yard waste generation per single-family household range from 150 to 500 pounds of leaves, 400 to 1000 pounds of grass, and about 300 pounds of wood and brush (on an annual basis). These numbers may provide a useful starting point, and certainly demonstrate the importance of recycling these wastes.

Most communities will need to conduct more detailed studies to determine the yard waste components of their local waste stream. Because they are often collected separately from other solid waste, leaves are one component for which some information may already be available. If residents employ landscapers, these yard wastes also should be estimated and provisions made

Table 3. Leaf Weight and Volume Estimates in Westchester County

Local Government	1985 Population	1988 Collected Curb Miles	Square Miles	1988 Tons	1988 Cubic Yards	Cubic Yards Per Collected Curb Miles	1988 % Leaves Still In Waste Stream
Briarcliff Manor	7,589	86	—	630-750	3,750	44	10
Bronxville	6,252	35	1	200-310	1,800-2,800	66	20
Croton-on-Hudson	7,252	34	5	502	4,831	142	20
Dobbs Ferry	10,067	56	2.5	220	2,000	36	80
Eastchester	20,236	112	5.25	900	6,350	57	25
Irvington	6,154	40	—	490-880	4,400	110	20
Lewisboro	10,890	20	—	—	1,183	59	20
Mt. Pleasant	26,599	215	25	1,400	13,000	61	20
New Rochelle	71,374	350	—	4,900	20,000	57	—
North Salem	4,709	—	—	90	800	—	—
Pleasantville	6,650	40	1.5	220	2,000	50	5
Scarsdale	17,576	180	6.5	4,300	37,250	207	0
Yorktown	33,934	160	40	125-500	2,000-4,000	19	—

for collection and composting; otherwise they may end up in the commercial waste disposal stream. Surveys of public works officials, haulers, landscapers and arborists can help develop the estimates needed to plan a facility.

The most accurate generation rates for any community will come from recording the amounts that are actually collected and delivered to the composting site during the first few years of operations. Careful record keeping will help quantify the impact of composting on the solid waste stream, provide a basis for measuring success, and permit more accurate planning in case of future program expansion.

Weight to volume conversion factors are necessary to determine the capacity and design of the processing site. Table 4 provides approximate densities of yard wastes. The density of yard waste varies with the waste source due to moisture content, texture, particle size and degree of compaction. The decomposition processes that occur during composting typically will reduce the weight of yard wastes by 30 to 50 percent and the volume by 50 to 80 percent through the process of volatilization and evaporation. This reduction becomes important both for sizing compost storage areas and for calculating potential revenues from compost sales.

IX. COLLECTION

Municipal yard waste is usually collected in one of two ways. There can be a separate curbside collection program, or a drop-off site(s) can be established where residents and commercial yard waste generators voluntarily deliver their yard wastes. Curbside systems are generally more expensive than drop-off systems. However, these costs may be justified on the basis of diverting more yard wastes from other disposal facilities. Ideally, a municipality should offer both strategies to increase the participation of residents and landscapers. This section details some of the programmatic options and discusses both opportunities and drawbacks.

Table 4. Density of Yard Wastes

Material	Condition	Typical Density (lbs/cu yd)
Brush and dry leaves	loose and dry	100-300
Leaves	loose and dry	100-260
Leaves	shredded and dry	250-350
Leaves	compacted and moist	400-500
Green grass	loose	300-400
Green grass	compacted	500-800
Yard waste	as collected	350-930
Yard waste	shredded	450-600
Compost	finished, screened	700-1200

A. Curbside

Curbside collection will likely generate significantly higher participation rates than drop-off sites, especially in areas where people are not in the habit of hauling their own trash. Weekly curbside collection, on the same day as regular garbage collection, usually has greater participation rates than monthly pickups, even when monthly pickups are mandated by source separation ordinances. However, if the collection of yard waste is going to occur on the same day as regular garbage pickup, some provision must be made for keeping the yard waste separate. Trailers, compartments, and separate yard waste collection vehicles are all options that have been successfully used in different communities. Collection of separated yard wastes can be combined but kept separate in the collection vehicle with curbside glass/can/paper recycling efforts, especially if all the materials go to a central recycling site.

Three general classes of yard waste can be collected at the curb: leaves, brush and woody wastes, and grass clippings. These are very different materials, and it may be necessary to apply a different collection strategy for each.

1. Leaves

Leaf collection requires a seasonal operation, beginning in mid-October and usually ending in mid-December. A spring yard waste collection generally yields 25 to 33 percent of the tonnage collected in the fall. (Collection in the spring is wetter and therefore generates a greater bulk density.) Some municipalities restrict their collection efforts to leaves from municipal street shade trees while other communities expect residents to rake their leaves to the curbside for collection. Frequency of collection varies widely among communities, depending on the number of trees as well as time and budget restrictions. Some communities collect as infrequently as once a year; others collect as often as five or six times a year.

Leaves can be collected in various ways during this relatively short season. They can be either bagged or loose, and can be picked up by different collection vehicles and equipment.

1a. Bagged Leaves

Three basic options exist for handling leaves in bags. Some communities are collecting leaves in non-degradable plastic garbage bags, and then debagging the leaves. A few communities are experimenting with degradable plastic bags, which may eventually decompose with the compost. Leaves can also be collected in biodegradable paper bags, which decompose within a few months and become part of the compost. Each of these options is discussed below, and a list of biodegradable paper bag manufacturers is provided in Appendix F.

Standard plastic garbage bags are inexpensive and readily available. Since they do not decompose, they must be separated from yard waste at some point before the compost is marketed. This debagging process tends to be fairly expensive, and should be considered when estimating total collection cost. Debagging by hand is one option. It is an unpleasant job that gets worse the longer leaves sit in their bags. Mechanized debagging can work, but will require a screening process to remove plastic pieces from the finished compost. Windrow turning machines will collect pieces of plastic bags on their drums, and may cause the bearings to overheat. In Muskegon, Wisconsin they have welded cutting blades onto a Wildcat turning machine drum to avoid this problem. Tub grinders can also shred bags, but this option will increase wear on the grinding surfaces. Since bits of plastic may remain in the finished compost, screening will be necessary before the compost can be marketed. In any case, using plastic bags will generate a significant volume of waste, and the economic and ecological implications must be considered.

Recently, biodegradable plastics have received a great deal of publicity. The decomposition of plastic bags with small amounts of added cornstarch has been evaluated in a number of composting facilities, with generally unfavorable reports. But new products are being developed that may prove more suitable to composting.

The cornstarch additive inserted in the polymer chains can be digested by microorganisms, causing the cornstarch to loose strength and break into small fragments. Some plastic bags have an ultraviolet accelerator that allows ultraviolet rays to energize and break down special linkage molecules. Both of these additives allow the long plastic polymer chains to break apart and begin the process of physical and chemical reduction.

However, biodegradation of these plastics is not rapid. To get the contained yard waste to start decomposing, even degradable plastic bags need to be broken apart to expose the yard waste to water and air. Because the degradable plastic bags currently on the market may take several years to fully decompose, they will still be visible at the end of the composting process. For communities trying to produce a finished product more quickly than that, this is likely to create difficulties in marketing the compost.

With either type of plastic bag, several colors are available. Clear plastic bags have the advantage of letting the collector see if household trash is mixed with yard waste in the bag. Because metal based inks and dyes are often used to pigment plastic bags, a non-toxic ink should be specified to avoid contaminating the compost product.

Paper leaf bags are definitely biodegradable and have been used successfully in many communities. Paper bags are more expensive than plastic bags, typically costing from 30 cents to 45 cents each. These bags hold 30 or 40 gallons of leaves, and may be single- or double-ply. Bags made with wet strength paper actually increase their strength when wet. They are sturdy enough to withstand rain and snow when placed at the curb, yet decompose in the compost pile. Paper leaf bags can be collected with a packer truck and compacted. The more bags that break in the compactor, or are torn apart by front-end loaders or other equipment at the compost site, the easier it will be to compost them. If the bags are not broken up initially, it may take a few more months to produce a finished compost, since the unbroken bags limit air and water movement in the windrows.

While paper bags have significant advantages in terms of handling and biodegradation, their cost can be a drawback. Some communities cover the cost through their solid waste budget, balancing the cost against the ease (and savings) in collection and processing. Bags can also be sold to residents at full-cost, a discounted price, or some combination of sales with a limited giveaway program. If bags are to be sold to residents to recover their cost, an appropriate incentive to buy them needs to be provided or the yard waste may end up mixed with refuse. As more communities charge by the container for mixed refuse collection, another problem can arise. Refuse may be hidden in yard waste bags as a cheaper disposal means. One possible solution is an ordinance banning yard waste in mixed refuse (and vice versa), as well as a rule that only properly separated bags will be collected. Appendix G presents a sample mandatory yard and leaf waste composting ordinance.

It is clear that the choice between paper versus plastic, and degradable versus non-degradable bags will influence other aspects of the composting process. Table 5 summarizes curbside collection options for bagged leaves. Be sure to consider the additional cost of providing, processing, and possibly disposing of bags when choosing a particular approach to curbside collection.

Table 5. Curbside Collection Options for Bagged Leaves

Bag Type and/or Collection Equipment	Advantages	Disadvantages
I. BAG TYPE		
A. Non-biodegradable Plastic	• Lower cost of bag (no cost to municiality). • Opportunity to hand separate out non-compostable debris when the bag is emptied.	• Costs and possible shortage of labor for emptying bags. • Risk of objectional odors being released when bad is opened. • Poor quality compost if leaves not debagged immediately. • Slow and labor intensive to unload, open bags, and windrow. • Must dispose of bags. • Pieces of plastic left in compost unless screened.
B. Biodegradable Plastic	• Convenience in bagging and greater compaction in bag. • Clear bags reduce probability of debris and mixed solid wastes.	• Higher cost of bag. • Availability and distribution of bags. • Increase in time needed for composting. (Not much experience thus far.) • Possible negative impact on finished compost quality.

C. Biodegradable Paper	• Convenience in bagging and greater compaction in bag. • Special bags reduce probability of debris and mixed solid wastes. • Lowest labor cost. • Best collection efficiency. • Ease of unloading and windrowing. • Keeps leaves off street. • Excellent quality compost. • Uses existing equipment.	• Higher cost of bag. • Availability and distribution of bags. • Shredding may be required. • Possible slight increase in time needed for composting.
II. COLLECTION EQUIPMENT		
A. Compactor Truck	• Large quantity per load due to compaction.	• High equipment costs unless the compactor is also used for other purposes.
1. Empty bag into compactor	• Maximum opportunity for removal of debris. • Efficient dumping into windrows.	• Inefficient use of compactor.
2. Empty bag at composting site	• Efficient use of compactor.	• Inconvenience in emptying non-degradable bags and formation of piles or windrows.
B. Dump Truck	• No specialized equipment.	• Small quantity per load in absence of compaction, with increased collection costs.

1b. Loose Leaves

There are a number of options for collecting loose leaves. All require residents to rake leaves to the curb. A vacuum truck uses a hose to suck leaves into a truck. A front-end loader can be used to scrape leaves from the street and put them into an open truck. A "claw" attachment or a street sweeper also can be used. The location of piles, and equipment and procedures for picking up loose leaves are summarized in Table 6. These pieces of equipment are discussed in Appendix D.

Compared to the collection of bagged leaves, bulk collection of loose leaves takes longer. While bulk leaves are easy to unload, not needing to be debagged, operators must check for contaminants that may have been collected with the leaves. Bottles, cans, balls, car batteries, and even lawn chairs have all been camouflaged in a pile of leaves. If compost is heavily contaminated with such debris, it will be difficult (and dangerous) to process and market.

Loose leaf collection saves residents the costs associated with bags, but the increased time and costs of loose collection reduce the number of pick-ups a community can afford. One or two collections in the fall with one early spring collection is typical.

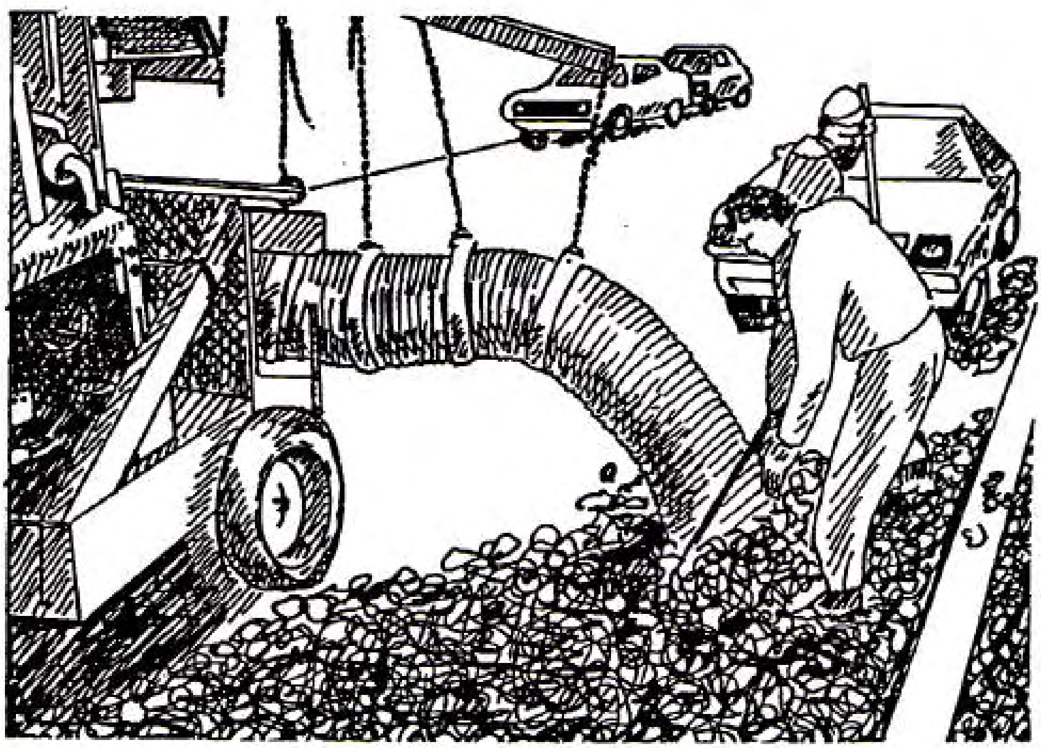


Table 6. Curbside Collection Options for Loose Leaves

Procedure and/or Equipment	Advantages	Disadvantages
I. LOCATION OF PILES		
A. Curbside	• Avoids problems associated with leaves in the street.	• Raking of leaves by collection crew, especially when collection is by front-end loader.
B. In Street	• Most convenient for collection in absence of parked cars.	• Danger to children playing in leaves. • Danger of fire from catalytic converters. • Either raking or repeated collection if cars are parked on the street. • Possible contamination of leaves by oil residues. • Need street sweeping for final clean-up.
II. EQUIPMENT AND PROCEDURE		
A. Vacuum Leaf Collector with discharge into wire or mesh covered box or for dump truck or trailer.	• Fast under ideal conditions. • Leaves partially shredded and compacted especially if somewhat damp. • Ease of unloading. • Eliminates need for street sweeping.	• Ineffective when excessively wet or frozen leaves become clumped. • Noise. • Moderate expense. • Dust if dry. • Specialized equipment. • Leaves on street awaiting collection.

		• Labor intensive/high labor cost. • High capital costs of new vacuum equipment. • May pick up stones or other contaminants. • Interferes with snow removal. • Traffic inconvenience.
1. Vacuum Mounting Options		
a. On front of truck (on hoist used for snow plow).	• Operator visible to driver.	• Not generally available with belt drive. • Street cleaners necessary afterwards. • Slow process.
b. On trailer with discharge into truck.	• Load one truck while another is in transit.	• Danger to operator and inconvenience from operation at rear of truck.
c. On trailer with leaf box.	• Can be pulled with any type of truck including one equipped for snowplowing and sanding.	• Inconvenience in backing to unload. • Danger to operator and inconvenience from operation at rear of truck. • Interferes with snow removal. • Traffic inconvenience.
2. Vacuum Drive Options		
a. Belt	• Reduces vibration from impeller to engine, which keeps down maintenance costs and increases service life.	• Higher initial cost.

b. On engine crankshaft	• Lower initial costs.	• Vibration from impeller increases maintenance and decreases service life.
c. Power-take-off	• Intermediate cost relative to other drive options. • Some reduction in vibration wear relative to direct engine drive.	• Not available on some units.
B. Catch Basin Cleaner	• Large units (12-inch suction hose) fast and effective with sufficient suction for collection of wet leaves.	• Small units (6-8 inch suction hose) slow and clog in excessively wet or freezing conditions. • Noise.
C. Front-end Loader and Dump Truck	• Specialized equipment optional. • Effective with wet and/or slightly frozen leaves. • Increased efficiency if front-end loader works with a claw attachment and final clean-up is with a street sweeper. • Moderate labor costs. • Produces a relatively uncontaminated compost.	• Requires that leaves be raked into the street. (A tractor pulled rake can be used only in suburban areas.) • Inefficient with dry leaves. • Possible need for street sweeping afterwards. • Requires alternate side of street parking. • Leaves on street awaiting collection.
D. Front-end Loader and Compactor Truck with chute for receiving leaves.	• Same as in C. except that effective capacity is much greater with a compactor.	• Same as in C.

E. Street Sweeper	• Low labor cost. • Uses existing equipment. • Ease of unloading.	• Leaves on street awaiting collection. • Risks contaminating compost with motor vehicle exhausts, oil, and debris. • Requires alternate side of street parking.

2. Brush and Woody Wastes

Brush and woody wastes are generated throughout the year, but primarily in the spring and fall. Because this type of material does not readily compact, curbside collection is difficult. Brush can be collected in bundles and taken to a central site for chipping, or it can be chipped by a mobile unit on the collection route. Chipping on route offers the advantage of minimizing handling and transportation costs, but eliminates the possibility of salvaging woody wastes for firewood. With either option, communities can set up seasonal brush pick-up days, consolidating the number of collection trips.

3. Grass Clippings

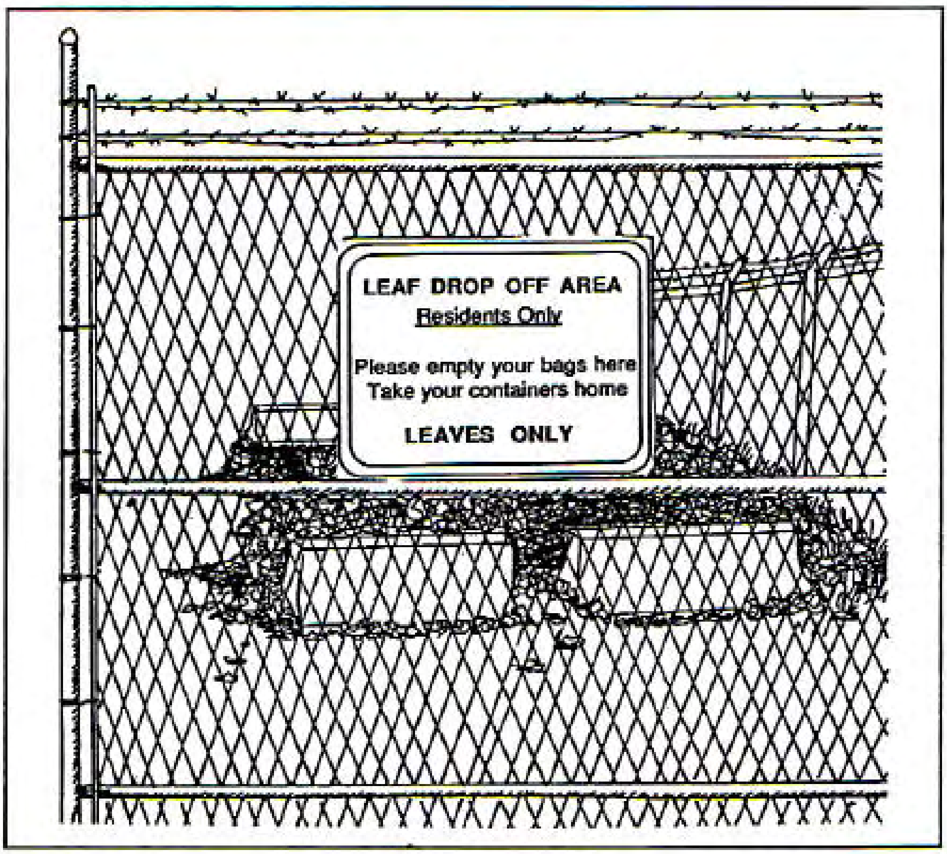
Grass clippings pose a particular challenge in yard waste composting. Because of their high nitrogen content, grass clippings decompose quickly. Oxygen will rapidly be depleted and strong odors will form when grass clippings are sealed in a bag for several days. When such bags are opened at the composting site, workers and neighbors may find these odors unacceptable.

Solutions are available, however. Perforated plastic or paper bags may permit enough air movement to reduce anaerobic odors. Some communities are using plastic containers for grass clipping collection. These containers are durable and easy to empty during collection, where odors can readily dissipate. Because grass clippings are heavy, containers need to be small enough to be handled by collection crews. A 20-gallon container can usually be dumped into a packer truck without causing undue strain.

Scheduling yard waste collection early in the week also can help solve odor problems associated with grass clippings. Most homeowners mow their lawns during the weekend (landscapers tend to mow on Thursdays and Fridays), so clippings collected on Monday will not have had much time to become anaerobic. If clippings get to the compost site quickly, they can be mixed with a porous, high carbon material such as chipped brush or partially composted leaves and anaerobic odors are less likely.

B. Drop-off Area

Drop-off collection requires a smaller investment, less effort, and less personnel than curbside collection. Because the responsibility is placed on waste generators to either transport the yard waste or handle it themselves through backyard composting or mulching, fewer residents are likely to participate than with curbside collection. However, this option may work as the sole management strategy in rural areas of medium or low population density or areas where there is no municipal or private waste collection. Drop-off areas also can complement a curbside collection program, providing a location for landscape contractors to deliver yard waste as it is generated.



Options for drop-off areas include a recycling center or collection trailers. In a recycling center, both yard waste collection and compost and chip distribution can be accomplished at a single location. Automobiles enter the drop-off area, pull over to a yard waste drop-off area, dump the yard waste, and then continue to drive to a finished compost pile where they can help themselves to compost. Piles of firewood and woodchips also can be made available. Collection trailers, on the other hand, can be left in neighborhoods for scheduled periods and serve as rotating drop-off sites. However, without supervision, unwanted garbage may also appear in collection trailers.

Only residents and contractors serving local residents should be allowed to use any drop-off site. In many communities, landscape contractors already haul a great deal of source-separated yard waste to the transfer station or disposal site. By offering landscapers a financial incentive (i.e., a reduced tipping fee), they will readily divert this material to a compost or chipping site. Charging fees based on volume and selling permits in advance can eliminate the need for scales or much cash handling at a compost site. A sample yard waste drop-off permit application form and sample yard waste delivery log are provided in Appendices H and I, respectively.

C. Scheduling and Public Notification

Notifying the public of the days when yard wastes will be collected will help promote a favorable attitude toward composting and recycling. Advance publicity is particularly important for seasonal programs such as leaf and brush collection. Appendices J and K are a sample pamphlet and newspaper advertisement designed for a leaf compost program. Notice of the collection dates, instructions on how the yard waste should be handled, and where they are to be placed can be done by a variety of means:

- Publish a map with designated areas and tentative collection dates based on favorable weather;
- Notify the media about the program by using news releases, news advisories, public service announcements and community calendar announcements. Municipal staff can write articles to be printed in local newspapers and newsletters;
- Distribute information sheets describing the composting project in detail and general information about the rationale for and process of composting. This material should be presented in nontechnical language that is easily understood. These sheets can be mailed out upon request and can be distributed at community events;
- Develop a poster to publicize the program. (Consider that many stores will not want to display large posters in their windows so it may be wise to print smaller posters.);
- In direct mail campaigns, include a brochure with a map and schedule of pickups for each neighborhood. Residents can also be notified in their water and garbage bills;
- Broadcast radio public service announcements giving the locations and operating times of each collection point and;
- Post notices on area streets four to five days prior to collection. (Check whether local laws prohibit posting signs before planning a sign campaign.)

Good communication regarding collection dates should reduce both the amount of foreign material collected and the quantity of yard waste that becomes mixed with other solid wastes. High public awareness of collection procedures also minimizes the likelihood that yard waste will sit on streets long enough to disperse into storm drains or catch basins.

X. SITE SELECTION

The selection of a municipal yard waste management site requires careful consideration.

Location, area requirements, and physical characteristics need to be evaluated. Appendix L is a yard waste management site assessment form which can be used to evaluate potential sites.

While many communities will opt for a single composting site, the option of several satellite facilities has several advantages. Smaller sites can be located closer to the collection route, cutting down on transportation costs. Their small size minimizes the impact on any given community. And odors, if they do occur, can more easily dissipate because of a greater dilution factor. Particularly for low-tech operations where equipment is readily mobile, small sites also can be very cost-effective.

A. Location

Several factors are particularly important in selecting a good yard waste recycling site. Easy year-round access to and from the site is essential. The location should minimize the distance to be traveled by collection vehicles. Access over uncrowded, nonresidential, hard-surface roads is preferable. Sites that may be appropriate include: unused paved areas, such as parking lots; the buffer area of a landfill or wastewater treatment plant; the buffer area around industrial installations and institutions; utility right-of-ways; and municipally-owned land used for buffer areas or storage.

Traffic considerations are important. If the site is in a residential area, local residents may demand the latest types of mufflers on all moving equipment. This may require performance specifications on bid documents for equipment. Noise barriers around the site may be necessary to minimize impacts on the neighborhood. If the public is allowed to drop off yard waste or pick up finished compost and mulch, proper access needs to be planned. Ideally, heavy equipment should have separate access routes from automobiles.

Finally, the local community must support the site's location. Siting problems sometimes result from citizen opposition. To ensure citizen support, any municipal yard waste management project should strive to educate the public and encourage its full participation in locating and planning the site.

B. Area Requirements

The area required for composting and chipping depends on the volume of yard waste processed, the desired volume reduction, the size and shape of windrows used, and the time required to complete the composting process. The actual area available may dictate a municipality's choice between composting methods. At a minimum, a compost site must have adequate area for at least one year's accumulation of yard waste, plus adequate additional space available to meet buffer zone requirements.

The leaf piles and turned windrow methods require more land than the more intensive forced aeration and in-vessel system methods. For a turned windrow facility, the NYS DEC suggests one acre for each 3500 cubic yards of leaves. Appendix M is a worksheet that offers one way of estimating the amount of land needed to compost a given volume of leaves. The following are guidelines for the composting pad, compost storage/curing area, staging area and buffer area for the turned windrow method.

1. Compost Pad

The size of a windrow and the spacing between each windrow depend on the site dimensions, the equipment used to aerate the windrows, and the geographic location of the community. A typical layout for a facility operated with front-end loaders is illustrated in Figure 7. Ideal soils for the compost pad are moderate to well drained, and gently sloping for good drainage. Since some soil likely will get mixed in with the compost during processing, the surface layer should be free of large stones. Impermeable compost pads are suggested only at sites where soils are highly permeable and groundwater rises to within four feet of the surface.

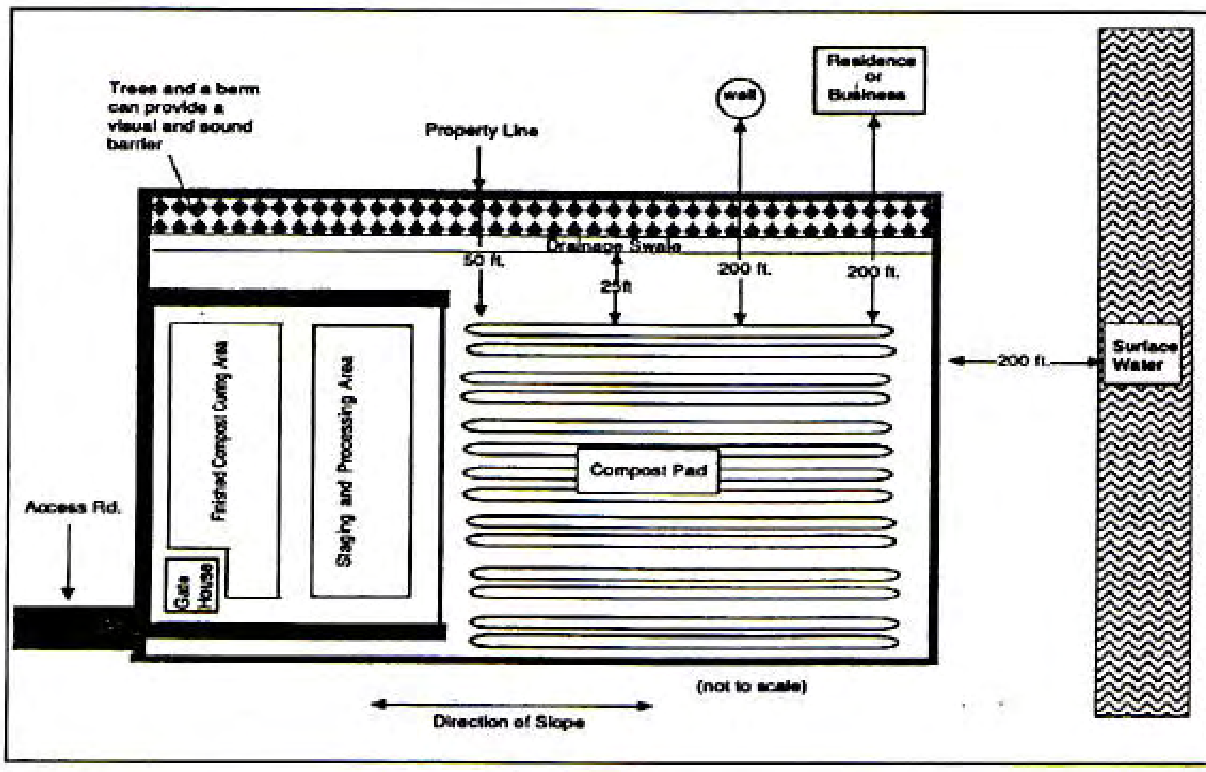


Figure 7. Compost Facility Site Layout

2. Curing Area

The curing process stabilizes the compost. Compost will need to be kept in the curing area for a minimum of one month. Longer storage time may be needed if there is a lag between when the compost is finished and the peak marketing season. During the curing stage, oxygen demand declines and the pile is recolonized by soil-dwelling microorganisms. Once cured, the compost will not generate foul odors. The curing area should be approximately one-fifth the size of the compost pad.

3. Staging and Processing Area

A staging area is needed at several phases of the composting and chipping processes. Space is required to unload incoming yard waste, mix and blend materials, chip brush, store reject material, shred compost, and load trucks for distribution. If plastic bags are separated from the yard waste, they need to be collected and disposed of properly. Depending on the amount of processing anticipated at the site, this area may need to be the same size as the curing area, or about one-fifth the size of the compost pad.

4. Buffer Area

A buffer zone is required between a composting facility and its neighbors to minimize possible odor, noise, dust, and visual impacts. A generous buffer between the compost site and sites of non-compatible uses can do much to eliminate potential complaints. Table 7 lists the minimal separation distances allowed under regulations of the New York State Department of Environmental Conservation (DEC).

Table 7. DEC Minimal Separation Requirements

Property line	50 feet
Residence or place of business	200 feet
Potable water well or supply	200 feet
Surface water body	200 feet
Drainage swale	25 feet

These set-back distances and resulting buffer area requirements also are presented in Figure 7. A landscaping plan that uses existing trees to enhance the appearance of the facility will reduce noise from operating equipment. Berms on all sides of the composting area can also help achieve noise reduction and visual screening of the site. When calculating the total site area requirements, be sure to realize that the buffer area may need to be several times the size of the active site, particularly for small operations. For example, in a site surrounded by businesses or homes as much as eight acres of buffer might be required for the first acre of active site. A location where much of that buffer is provided by adjacent undeveloped land, such as a park, has obvious advantages.

C. Physical Characteristics

1. Slope and Grading

A gentle slope of at least one percent is needed to avoid ponding which can cause odor problems. Slopes above eight percent are unsatisfactory, causing erosion and difficult vehicular access and equipment operation. A slope of two to three percent is generally considered ideal. The compost pad area needs to be graded to minimize ponding and to help maintain a stable base for equipment operation. Initial site preparation may require surfacing with gravel or compacted sand to allow year-round use. Windrows should run parallel to the slope rather than across the slope to allow runoff to move between the piles rather than through them. Any runoff coming onto the site should be diverted away from the active composting area. Yearly maintenance should include regrading when necessary.

2. Groundwater and Surface Water Separation

New York State Department of Environmental Conservation regulations do not allow a compost facility to be sited in a floodplain or wetland unless provisions have been made to restrict water. Depth to seasonally high groundwater should be greater than 24 inches. A higher water table may lead to flooding of the site which will make equipment access and operation more difficult. Flooding can also promote less desirable anaerobic conditions in the compost process.

A high water table will also increase the likelihood of leachate contamination of groundwater or nearby surface water. The shorter the distance leachate percolates through unsaturated soil, the less it undergoes natural biological and physical treatment. The DEC permit application will ask for the minimum depth to groundwater. Soil surveys that provide information on depth to groundwater, percolation rate, and soil types may be available from the county soil survey, produced by the Soil Conservation Service (SCS). Soil scientists can determine the depth at a specific site by examining the soil profile. In the spring, when groundwater is high, the depth can be measured by digging two holes, six feet deep, and checking them a few days later to determine water table depth.

3. Percolation

Moderate to good soil percolation rates are desirable to avoid standing water and minimize the leachate and rainwater that run off the site. Surface water should be diverted away from the compost site using a diversion ditch, an interceptor berm, or an interceptor drain.

Good soil percolation characteristics allow equipment to operate year-round. An impervious surface such as a concrete or asphalt pad offers advantages in terms of vehicle access, equipment operations, mud and dust prevention, and groundwater protection, but these advantages must be weighed against the difficulties in managing the increased runoff.

4. Water Supply

Water is important both for adding moisture to the compost material and for fire protection. Hydrants connected to a public water supply are ideal. Water also can be supplied by a nearby lake, stream or well, or water truck. Approximate water requirements for leaves as they are first handled are 20 gallons per cubic yard, depending on how wet the leaves are when collected.

5. Security

A gate and fence can be used to control illegal vehicular access and prevent illegal dumping when the site is closed. A fence surrounding the facility will also prevent wind from blowing debris off the site. Surveillance of the site by the police may, in some cases, be necessary.

XI. HEALTH AND SAFETY CONSIDERATIONS

Proper attention to health and safety concerns can minimize most occupational risks at compost facilities. While composting is not an inherently dangerous activity, precautions are necessary to protect against injury and possible illness.

A. Equipment Operation

Safety concerns in composting relate primarily to equipment. If front-end loaders or other standard heavy equipment are used, ear protection and other normal safety precautions apply. Additional precautions must be followed when specialized windrow turning equipment is used. These typically contain mixing flails that rotate at a high rate of speed, and should therefore be well shielded from human contact. As these flails rotate through the compost windrow, they will eject foreign matter from the windrow. Stones and other foreign objects can become dangerous projectiles, and can be thrown a long distance behind the turning equipment. Thus, equipment operators must ensure a safe clearance both around and behind the operating machinery.

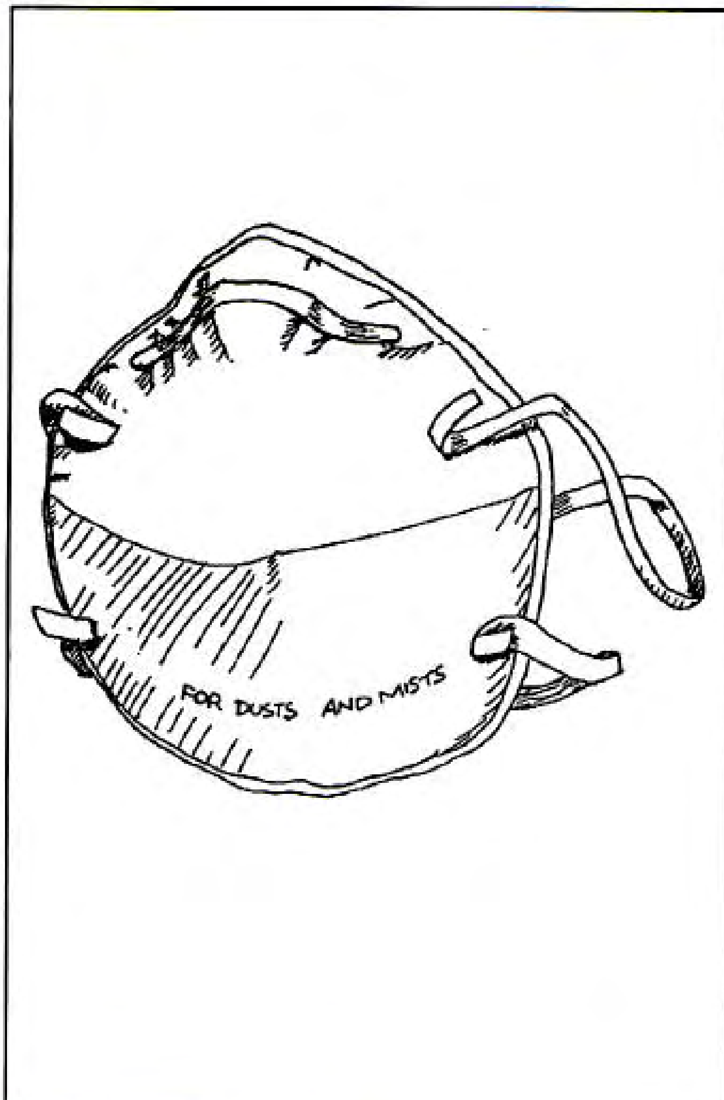
Public access to the composting facility should be restricted, particularly during turning, shredding, grinding or transport operations. To minimize risk, finished compost could be hauled from the site to neighborhood distribution centers such as recycling drop-off centers.

B. Fire Precautions

Fires are rarely a problem in outdoor composting operations. Because the inside of the windrows should be damp, compost normally burns poorly. However, if the material does dry out and gets too hot, combustion can occur. Organic material can ignite spontaneously at moisture contents between 25 and 45 percent. This sometimes happens to stored hay or silage, and can happen to compost as well. First, however, the material has to heat to over 200°F (93°C), which typically requires a pile over 12 feet high. Keeping the windrows less than 10 feet tall, and turning the compost when temperatures exceed 140°F (60°C), not only constitutes good compost management, but provides fire protection as well. In the event of fire, whether by spontaneous combustion or vandalism, the site must have delivery capacity and an adequate water supply. Maintaining clear aisles between windrows will provide easy access in case of fire.

C. Health Concerns

Health concerns relating to compost are dependent on both the individual and the material being composted. While few human pathogenic organisms are found in vegetative wastes or farm animal manures, normal sanitary measures (i.e., washing hands before touching food, eyes, etc.) are important. While many compost operations have run smoothly for years without unusual health or safety problems, there are some unique health concerns in composting of which workers should be aware. By understanding these concerns, it will be easier to recognize problems early and seek an appropriate remedy before serious complications develop.



Just as individuals vary in their resistance to disease, a few individuals may be particularly sensitive to some of the organisms in compost. The high populations of many different species of molds and fungi in an active compost process can cause allergic reactions in sensitive individuals, though most experience no adverse reaction. Conditions that may predispose individuals to infection or an allergic response include: a weakened immune system, allergies, asthma, a punctured eardrum, or some medications such as antibiotics and adrenal cortical hormones. Workers with these conditions should not be assigned to a composting operation.

One specific concern, which has been documented at composting facilities, is caused by the fungus *Aspergillus fumigatus*.

This fungus is naturally present in decaying organic matter, and will colonize the waste material handled at a compost facility. Excessive exposure to spores from this organism can cause allergic problems or respiratory infection in 5 to 10 percent of the general population. To minimize exposure to dust and molds, Occupational Safety and Health Administration (OSHA)-approved dust masks or respirators should be worn under dry and dusty conditions, especially when the compost is being turned. If, following these precautions, workers still develop an infection or show an allergic reaction to compost, they should consult a medical professional.

XIII. PERSONNEL

A. Requirements

The number of personnel needed for a yard waste recycling operation largely depends upon the method of collection, since this is the most labor-intensive aspect of yard waste management. Table 8 lists personnel requirements for the various leaf collection options. In curbside collection, the frequency of pick-up and total curb miles will determine personnel requirements. At the composting and chipping facility, personnel are needed to: monitor yard waste deliveries; supervise the compost operation; run the composting and chipping operations; maintain records; and transport finished products. During the fall leaf collection period, continuous staffing is usually necessary. However, full-time monitoring is not required in other seasons at sites that only compost leaves.

Additional personnel will be needed for some types of operations. If there is a public drop-off site, more employees will be needed to run the facility on a busy spring or autumn weekend than on a quiet weekday. If nondegradable plastic bags are used, they must be opened soon after delivery. Manual debagging requires considerable labor (typically over an hour for each ton of leaves). During fall leaf collection, seasonal labor may be needed to assist in raking leaves and loading trucks, and a mechanic should be dedicated to vehicle maintenance to ensure that vehicles are operating at all times. It may be possible to borrow personnel from other local and/or county departments such as public works, highway maintenance or parks and recreation to assist with these labor-intensive activities.

Table 8. Personnel Requirements for Leaf Collection

Collection Options	Collection Equipment	Personnel Needed Per Route
Paper bags	• Compactor truck • Open truck	• Truck operator and 1 collector • Truck operator and 1 collector
Plastic bags	• Compactor truck • Open truck	• Truck operator and 1 collector • Truck operator and 1 collector
Loose	• Front-end loader and open truck • Street sweeper • Vacuum equipment	• Loader operator and truck operator • Sweeper operator • Truck operator and vacuum crew of 1-3 persons

B. Training

Operator training is crucial for good site management. While yard waste recycling is not particularly complicated or sophisticated, knowledgeable operators can make the difference between success and disaster. While this manual is primarily geared toward facility planners, most of it will be useful to operators as well. A separate set of operator's fact sheets have been developed that focus more directly on the information needed by facility operators. A training video will be available in the spring of 1991 for use in training programs as well as review by newly hired employees. Cornell Cooperative Extension provides training seminars, facility tours and equipment demonstrations for municipal officials and compost facility operators. Contact your county Cornell Cooperative Extension office for information about these training materials.

XIV. MARKETING

The goal of yard waste recycling is to transform waste into a useful product. That product must then leave the chipping and composting site and find its way to gardens and lawns for the recycling process to be complete. Effective distribution and marketing are crucial to the success of a project. Demand for chips, mulch, and finished compost will depend on a number of interrelated factors. These factors include consistent quality, seasonality, cost, and consumer education.

A. Product Quality

Product quality rests on its appearance, uniformity of consistency, level of impurities and chemical composition. Chipping, shredding, and grinding equipment produce products in a range of sizes and shapes, which need to be matched to local demand. Using specialized processing equipment, such as a windrow turning machine, shredding and/or screening can improve compost appearance and consistency, as well as reduce the length of the processing period. Minimizing contamination of compost and chips with foreign objects like stones, sticks, glass, and plastics will also provide a better quality product.

The public also will be concerned about the chemical composition of the compost, particularly nutrients and heavy metals. The fertilizer value of compost is based on the level of primary nutrients available. The primary nutrients are nitrogen (N), phosphorus (P) and potassium (K). They are represented on fertilizer bags as N-P-K on a percent dry weight basis. Typical nutrient values for yard waste composts range from 1-0-0 to 2-1-1, but can be extremely variable within that range. Table 9 presents chemical characteristics of yard waste compost produced at a variety of sites in New York and Massachusetts.

Table 9. Chemical Characterization of Yard Waste Compost (Dry Basis)

Nutrient	Range (%)	Mean of Leaf Compost (%)
Nitrogen (total)	0.3 - 2.0	0.6
Phosphorus	0.03 - .5	0.1
Potassium	0.1 - 2.0	1.1

Materials sold as fertilizers in New York State must guarantee the advertised analysis and be registered with the New York State Department of Agriculture and Markets. Most composts are classified as soil conditioners, rather than fertilizers, because the nutrient content is relatively low and variable. While the nutrient levels in compost are low compared to commercial fertilizers, at high rates these values do add up and can be used in calculating application rates. Compost application rates for some uses are listed in Table 10.

Table 10. Compost Application and Use

Landscape use	Approximate rate* (lbs/1000 sq. ft.)	Comments
Establish new lawns and athletic fields	3000 to 6000 (1 to 2 inches)	Incorporate into top 4 to 6 inches of soil
Topdress established lawns	400 to 800 (1/8 to 1/4 inch)	Broadcase uniformly on grass surface
Shrub and tree maintenance	200 to 500 (1/16 to 1/4 inch)	Work into soil or use as mulch
Container mix	Not more than 1/3 by volume	Blend with perlite, vermiculite, sand, bark

*1000 pounds = approximately 1 cubic yard

Potential compost users may express concern about contamination of yard waste with lead and other trace heavy metals. Ten years ago, lead was a common contaminant of yard waste compost, having been deposited on leaves and street sweepings from automobile exhaust. As the consumption of leaded gasoline decreases, we have seen a corresponding decrease in the amount of lead in yard waste composts.

The low levels of lead found in yard waste today are rarely a constraint on marketing or use. DEC's criteria for Class I sludge or solid waste compost, which can be distributed in an unrestricted manner, requires that it must not contain lead levels greater than 250 ppm (parts per million) dry weight. Yard waste compost averages much less than these lead levels (typically around 50 ppm), and is exempted from these regulatory criteria. Nonetheless, high concentrations may be found in street sweepings or in yard waste from heavily trafficked areas, and may be worthy of occasional monitoring. To help put these values in perspective, the background concentrations of lead in soils commonly range from 2 to 200 ppm.

Another concern often raised by potential compost users is the presence of pesticide residues in yard waste compost. Detailed testing by independent labs on a range of compost samples has not identified any compounds present at levels that would constrain compost use. Pesticides on the market today have been designed to break down rapidly in soil and it appears they do during composting as well.

Compost product characteristics can be tested by many environmental laboratories. The DEC has a list of labs that participate in their certification program. Testing of compost for nutrients or heavy metals also can be arranged through the county office of Cornell Cooperative Extension or by sending samples directly to the Pomology Nutrient Analysis Laboratory, 135A Plant Science, Cornell University, Ithaca, NY 14853. A composite sample, composed of many small samples from different locations in the windrows or curing piles, will provide a more representative result. Subsamples can be mixed in a clean bucket, then ship about one quart in a double resealable plastic bag. A compost quality analysis order form is provided in Appendix U.

Marketing different products (e.g., finely shredded compost and coarse woody mulch) can produce better revenues and increase the likelihood that all products will be sold. Wholesalers and retailers of compost products sometimes add other ingredients for special users or markets. Possible treatments include the addition of:

Ammonium sulfate to increase nitrogen content.

Blood meal to increase nitrogen content. It is easily soluble and stimulates microbial activity.

Bone meal to increase phosphorus and alkalinize soil.

Cocoa bean hulls to serve as a soil conditioner or as a mulch.

Ferric sulfate to add iron and dark color as well as acidity.

Gypsum to replace sodium in alkaline soil with calcium.

Kelp meal to increase potassium and trace elements.

Lime to increase pH.

Peat to hold water. When dry, it is very light and therefore decreases shipping weight.

Perlite, a puffed volcanic ash, to increase aeration, water holding capacity and drainage.

Sand to increase workability and porosity.

Sulfur to lower soil salinity and increase acidity.

Vermiculite, a puffed mine mineral, to increase aeration, water holding capacity and drainage.

B. Seasonal Demand

A reliable supply of compost and mulch products is important if it is to be used on a regular basis by businesses, agencies, and institutions. If the supply of finished product does not match the season(s) of high market demand, stockpiling may be required. Partially finished compost also may be sold as a mulch product, or wholesaled to a distributor with storage space or more processing equipment.

If compost will need to be stored for lengthy time periods, covered storage may be required. Finished compost readily adsorbs water and wet compost can be difficult to market. A large shed or barn-like building is ideal for this purpose, but tarps also can be used on a temporary basis. Remember that a tarp will cut down on air circulation, which may lead to anaerobic conditions in the compost. If stored compost has become anaerobic, aerate it thoroughly before marketing the materials. Anaerobic compost can be phytotoxic to plants - a compost marketing nightmare!

C. Cost

Municipal use or sale of recycled yard waste products can offset some of the expenses of collecting and processing yard wastes. While many municipalities use most of their compost and mulch in their own operations or develop give-away programs for residents, increasing numbers of municipalities are selling their products. Sales can be either retail (bagged or bulk) or wholesale (bulk) to compost distributors. Depending on the municipality's revenue goals, the strength of local demand for horticultural products, and the quality of the yard waste products, the price can range from a nominal fee up to the price of peat moss or bark mulchess. The closer chips or compost approach the quality, uniformity, and consistency of competitive products such as shredded bark or peat, the higher their relative value. Screening and shredding of compost will make the finished product more desirable, and in a strong market can exceed the substantial added costs by perhaps doubling the market value of the finished product. Coarse screenings from compost can often be combined and marketed with chips, or they can be reintroduced into the composting process.

Communities planning to use compost for municipal purposes, such as reclamation of a closed landfill or refurbishing parks and roadways, should obtain a written commitment from the appropriate local department to satisfy the DEC requirement that markets be identified before the project is permitted. Municipalities can examine how much they currently pay for fertilizer, topsoil and peat to evaluate the potential municipal cost savings and demand for finished compost and mulch.

A municipality also may give chips and compost to residents. A giveaway program should be promoted as a public service, and need not imply a low value product. Such programs also are useful as a public relations tool, helping promote public support for the yard waste recycling facility. Many giveaway programs require the public to pick up the chips and finished compost at a centrally located distribution site, which in some cases is combined with a recycling drop-off site. This approach acts to increase community awareness about recycling and waste reduction, and returns a tangible product to residents for their efforts to recycle. People are expected to bring their own containers and loading equipment. Most municipalities give chips and compost to residents and charge a nominal fee to bulk users. A municipality also may want to charge a fee to non-residents.

The cost involved in establishing a giveaway program is minimal. It may include the cost of trucking finished compost to more centrally located distribution sites and the cost of site maintenance, but does not generally require full-time dedicated staff.

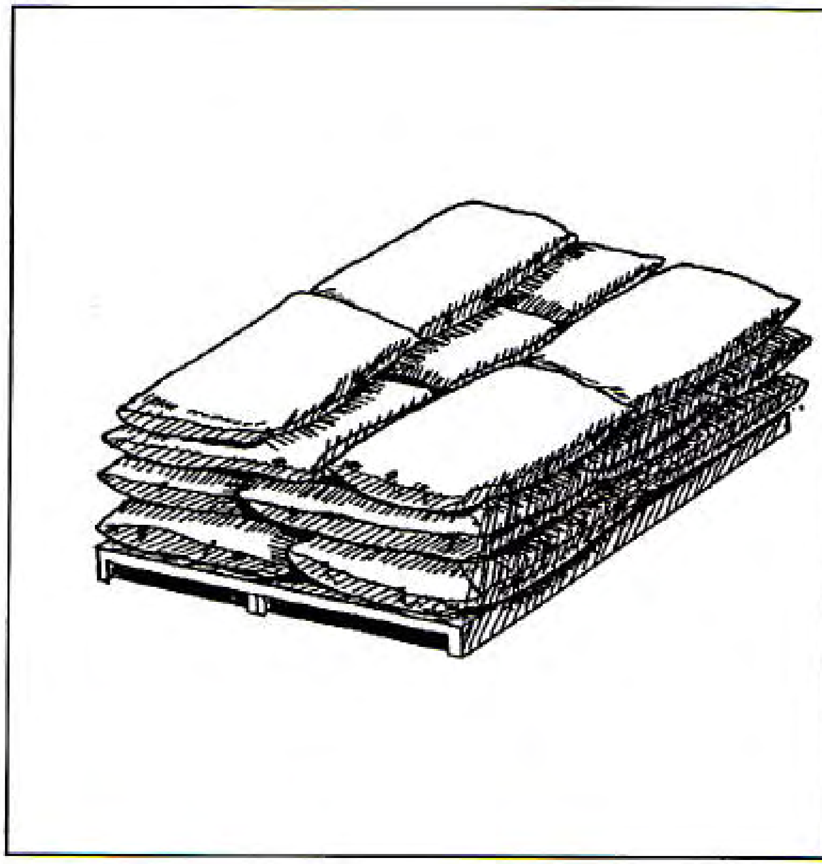
Many individuals and institutions purchase soil amendments, such as topsoil, manure, saw dust and peat moss, having similar attributes to mulch and compost. Table 11 lists some potential compost users.

Table 11. Potential Compost Users

Bulk Users	Retail/Wholesale	Processors
Land reclamation	Garden centers	Fertilizer contractors
Landfill cover	Home gardeners	Fertilizer manufacturers
Parks	Topsoil	
Highway maintenance		
Cemeteries		
Schools		
Nurseries		
Greenhouses		
Sod farmers		
Golf courses		
Lawn care		
Landscape contractors		
Industrial park grounds		

A market survey can help determine who the potential users are and the level of their demand. This survey should solicit information about the preferences of customers with regard to product quality, type, and form of packaging. Appendix V is a telephone market survey form that assesses the type of products desired and prices that consumers will pay for yard waste products.

Many municipalities lack the promotional expertise and sometimes the enthusiasm for marketing the finished products. In such cases, the marketing can perhaps be better done by the private sector. The municipality could contract with an independent firm to market some of the compost and mulch, while retaining a percentage for utilization by the municipality. Currently there are several large companies in the Northeast that buy compost from communities to bag, sell, and distribute.



D. Education

Education about yard waste recycling should underlie all marketing efforts. Conduct a public education program to demonstrate how compost is a valuable resource. Compost is a manufactured version of humus, the sweet smelling, decomposed organic material that gives soil its crumbly texture. Benefits of compost include:

- increased water retention;
- improved resistance to water and wind erosion; and
- enhanced soil tilth.

Publicity should emphasize these benefits, and also explain how and when compost and mulch are available. Encourage the public to see the benefits of compost firsthand by demonstrating its use at flower and garden shows, schools, and public parks. A demonstration can present the various uses and application rates of compost to achieve soil improvement and better plant growth. With a comprehensive public education program, chips and compost should practically sell themselves.

A wide range of yard waste recycling materials are available through Cornell Cooperative Extension. Appendix W contains a list of materials that pertain to home composting and compost use. Brochures, slide sets, posters, and books can all help support your community's compost education program.

XV. FINANCING A MUNICIPAL COMPOSTING FACILITY

The economic advantages of yard waste recycling facilities are based largely on the avoided costs of disposal. Avoided cost refers to the money that would have had to have been spent to take and dispose of yard wastes at a landfill or incinerator. When composting costs are balanced against these avoided transport and disposal costs, composting often contributes to lower overall long term waste management system costs.

If the compost site is closer than the primary disposal site, savings in transport costs also will result. Since finished chips and compost can be used as a substitute for mulch or topsoil in municipal landscaping, those savings also should be considered. If sold commercially, the finished products can generate revenues, which help defray processing costs.

The capital costs, operating costs, and the revenue received for the finished product vary greatly among different composting operations. Appendix X is a budget worksheet to help municipalities determine yard waste processing costs. Capital expenditures include costs of equipment, site acquisition, and construction expenditures. Operating costs will involve labor as well as fuel, maintenance, and utilities. Depending on the selected collection and processing system, other costs might include disposal of rejects and contaminants, contractor or consultant fees, training, and publicity. Less tangible savings in terms of landfill space, disposal fees and transportation costs also should be considered when determining the cost-effectiveness of the project.

Capital for facilities and equipment can come from either borrowed funds or current revenues. An alternative is to contract with private firms for chipping or composting service, which may include equipment, labor, or management supervision, etc. in various combinations Borrowing sources include: general obligation bonds, revenue bonds, bank loans, and leasing. Private financing sources are industrial revenue bonds and leveraged leasing. The financial status of the municipality, voter attitude, legal constraints on debt limits or long-term contracts, and the magnitude of the project will determine which option suits a municipality best.

Funds for the yard waste management program should be set aside in a segregated account to be available as needed for capital replacement and operating expenses. These funds should reflect the full cost of the service. The money necessary can come from either general fund revenues or user fees.

XVI. PUBLIC ACCEPTANCE AND COMMUNITY INVOLVEMENT

Any community planning a composting and chipping facility must have strong local support for the project. This requires that the public be informed of the benefits of composting and collection schedules. Most residents already manage yard wastes separately and may be accustomed to putting them out for special collection. Incentives such as free bags, prizes, or a lower disposal fee can get the program off to a positive start. A source separation ordinance prohibiting the mixing of residential recyclables with mixed waste can be passed to encourage those who are reluctant. Those not complying may need to be fined or denied collection services.

Attractive, legible and informative signs at the entrance of the facility can improve public relations and minimize confusion at the site. They should indicate: the nature of the project; facility name; operating hours; and business address and telephone number of the operator. Other signs should direct collection vehicles to the unloading areas and indicate traffic circulation patterns. If there is a drop-off site, signs should guide the public to the site and clearly present the rules for delivery of yard waste.

Local residents near the facility may be concerned about odor, noise, rats, insects, traffic, and aesthetics. Officials can assure residents that serious problems do not occur in properly managed facilities, and that if they do occur, corrective measures that are readily effective can be taken. Offering honest and detailed information about the experiences of other communities that have yard waste management facilities can do much to allay residents' concerns. Officials should welcome input from residents, who may have suggestions that improve the facility and minimize neighborhood impacts. Cornell University's Media Services Division has a slide set on municipal composting that is available for use in educational programs. These and other resources to promote public awareness are available through the local Cornell Cooperative Extension office.

With signs of the solid waste capacity crisis all around us, public support for chipping and composting yard waste is growing. Compatibility with other recycling efforts makes composting and chipping not so much something completely new, but instead another version of reducing and re-using our wastes. The appeal of municipal yard waste recycling lies in giving communities some creative control over the management and use of a portion of their own wastes.

GLOSSARY

Acid. pH below 7 on scale of 0 to 14. Normal product of early stages of decomposition, characterized by hydrogen ions.

Aerated Static Pile Composting. See static pile composting.

Aeration. Providing air and oxygen to aid aerobic decomposition.

Aerobic. Characterized by the presence of oxygen.

Aerobic Composting. Decomposition of organic wastes by microorganisms in the presence of oxygen. See composting.

Alkaline. pH above 7 on a scale of 0 to 14. Containing bases (hydroxide, carbonates) that neutralize acids to form salts.

Anaerobic. Characterized by the absence of oxygen.

Anaerobic Digestion. Decomposition of organic wastes in the absence of oxygen.

Berm. A barrier adjacent to a facility to intercept and deflect water and noise; can also provide visual screening.

Biodegradation. The transformation by microorganisms of dead organic materials, such as fallen leaves, into stable humus. See decomposition.

Buffer Zone. Area between the composting facility and homes or other sensitive land uses, that shields these neighboring uses from impacts of the operation. A buffer zone that is vegetated can contribute to visual screening and noise interception.

Bulking Agent. Relatively large particle materials such as wood chips which create air space within compost.

Compaction. Compressing wastes to reduce their volume. Compaction allows for more efficient transport, but may reduce aeration.

Compost. Decomposed, humus-like organic matter produced through composting. Depending on the waste source, compost may have some nutrient value and generally improves soil characteristics.

Compost Pad. An area within the composting site where organic materials are processed. If not a hard surface, the pad should be constructed of material that drains well and will support heavy equipment in all weather conditions.

Composting. A process of accelerated biodegradation and stabilization of organic material under controlled conditions.

Composting Facility. A facility that produces compost from the organic fraction of the waste stream.

Cubic Yard. A standard measure of waste volume. There are 27 cubic feet in a cubic yard. For compacted leaves, one cubic yard is roughly equivalent to 500 pounds or 1/4 ton, assuming an average rate of compaction and moisture content.

Curing. The final stage of composting, after much of the readily metabolized material has been decomposed, that provides additional biological stabilization.

Decomposition. The breaking down of dead organic material, such as fallen leaves, by microorganisms. This process turns small biologically active molecules, such as starches, into large, very complex and stable molecules that make up humus.

Fermentation. Anaerobic decomposition involving only organic compounds.

Flail. A metal flange or tine attached to a rotating shaft for moving, mixing and aerating leaves.

Forced Aeration (static pile). See static pile composting.

Front-end Loader. A tractor vehicle with a bucket-type loader at the front end of the vehicle.

Groundwater. Water in a zone of saturation below the ground surface.

Heavy Metals. Metallic elements with high molecular weights. Some elements present human health risks at certain concentrations; some may be phytotoxic to plants, and others may adversely affect livestock. While high concentrations can be harmful, low concentrations of some heavy metals such as copper and zinc are essential trace elements for life processes.

Humus. That more or less stable fraction of the soil organic matter remaining after the major portion of added plant and animal residues have decomposed. Usually it is dark in color.

Inorganic. Containing no carbon-to-carbon bonds; examples of inorganic substances include ammonia nitrogen, phosphorus, and potassium.

In-Vessel Composting. A method of composting organic wastes including a variety of systems involving mechanical agitation, and/or forced aeration, that is normally enclosed within a building.

Leachate. The liquid that results from ground or surface water that has been in contact with solid waste and has extracted material, either dissolved or suspended, from the solid waste.

Leaf Mold. Compost composed entirely of leaves, sometimes only partially decomposed.

Leaf Piles. A passive method of composting, where leaves are placed in large piles until a usable product is developed, a minimum of 2-3 years.

Lignin. An amorphous polymeric substance related to cellulose that, together with cellulose, forms the woody cell walls of plants and the cementing material between them.

Mesophilic. Favoring an environment of moderate temperature between 40°-110° F (4°-43° C). Mesophilic microorganisms are most common at the beginning and later stages of the compost process.

Metabolism. Chemical processes necessary for life.

Microbe. See microorganism.

Microorganism. Living organism of a size such that it can be seen only with a microscope.

Mulch. Material put between rows or around the base of plants to reduce the loss of moisture from the soil and discourage the growth of weeds. Grass clippings, wood chips, sawdust, and straw are commonly used as mulches.

Municipal Solid Waste. Garbage, refuse, trash and other solid waste from residential, commercial, and industrial activities.

N:P:K Ratio. The ratio of nitrogen to phosphorus to potassium in a compost product; indicates fertilizer value.

Non-compostable. Incapable of decomposing naturally or of yielding safe, non-toxic end products. Non-compostable materials include glass, batteries, cans, etc.

Nutrients. Minerals and organic compounds that provide substance for organisms.

Organic. Containing carbon-to-carbon bonds.

Organic Waste. Waste composed of materials that contain carbon-to-carbon bonds and are biodegradable. Includes paper, wood, food wastes, yard wastes and leaves.

Oxygen Demand. The requirement for oxygen exerted in aerobic decomposition by microbial respiration.

Pathogen. Any organism capable of producing disease or infection; often found in waste material. High temperatures (above 131°F or 55°C) over a consecutive period (3 days) have been shown to effectively kill pathogens.

Percolation. Downward movement of water through the pores or spaces in rock or soil.

pH. A measure of how acidic (pH less than 7) or basic (pH above 7) a material is on a scale of 0 to 14. A pH of 7 is considered neutral.

Putrescible. With a tendency to become putrid. Some organic materials are prone to degrade rapidly, giving rise to putrid odors.

Resource Recovery. A term used to describe the extraction of economically useful materials and/or energy from solid waste. Often refers to the burning of waste for energy.

Respiration. Metabolic functions consuming oxygen.

Run-off. Any liquid originating from any part of a composting facility that drains over the land surface.

Screening. The process of passing compost through a screen or sieve to remove large organic or inorganic materials and improve the consistency and quality of the end-product.

Self-heating. Spontaneous increase in temperature of organic masses resulting from microbial action.

Shredder. A mechanical device used to break up waste materials into smaller pieces, usually in the form of irregularly shaped strips. Shredding devices include tub mill grinders, hammermills, shears, drum pulverizers, wet pulpers and rasp mills.

Soil Amendment / Soil Conditioner. A soil additive that stabilizes the soil, improves its resistance to erosion, increases its permeability to air and water, improves its texture and the resistance of its surface to crusting, makes it easier to cultivate, or otherwise improves its quality.

Soil Profile. The characteristics of the soil and how they change with depth. Coloration and other features can be used to determine soil types, texture, and seasonally high water table.

Solid Waste. Any unwanted or discarded solid materials, including solid, liquid, semisolid or contained gaseous materials. Solid wastes are classified as refuse.

Stabilization. The decomposition of compost to the point where it neither reheats when wetted nor gives off offensive odors.

Staging Area. A temporary holding area where newly received leaves are received, mixed or debagged before being transfered to a compost pad.

Static Pile Composting. A method of composting in which oxygen and temperature levels are mechanically controlled by blowing air through a large stationary pile.

Swale. A slight depression often for drainage, in the midst of generally level land.

Thermophilic. Favoring higher temperatures ranging from 113°F - 155°F (45°C - 68°C). Thermophilic microorganisms thrive when the compost pile heats up.

Vector. Any organism capable of transmitting a pathogen to another organism, such as mosquitoes, rats, etc.

Volume Reduction. The processing of waste materials to decrease the amount of space they occupy. Compaction, shredding, composting and burning are all methods of volume reduction.

Wet Ton. Two thousand pounds of material, "as is". It is the sum of the dry weight of the material plus its moisture content. Yard waste weighed on truck scales would typically be reported this way.

Windrow Composting. A method of composting leaves in elongated piles. The piles or "windrows" are turned periodically to aerate and mix the leaves, speeding up the decomposition process and reducing odors.

Yard Waste. Garden wastes, leaves, grass clippings, weeds, brush.

APPENDIX A

STEPS IN STARTING A YARD WASTE MANAGEMENT PROJECT

Starting a successful composting program requires proper planning. The various tasks associated with each project phase are listed in the following outline.

I. Feasibility Study and Conceptual Design

1. Identify quantities and composition of wastes for municipal composting
2. Identify and investigate end uses of the final product
3. Evaluate existing collection system, identify required modifications
4. Identify and evaluate potential sites
5. Evaluate potential environmental impacts
6. Identify institutional requirements and permit requirements
7. Assess public support
   - for home composting
   - for participation in municipal collection
   - for using final compost product
8. Complete conceptual design, including
   - site requirements
   - general design and site layout
   - equipment requirements
   - operating procedures
   - personnel requirements
9. Conduct preliminary economic analysis, including
   - capital costs
   - operating and maintenance costs
   - potential revenues
   - avoided costs
10. Identify financing options
11. Formulate conclusions and recommendations
    - select site
    - determine owner/operator
    - determine financing methods and obtain funds

II. Design and Engineering

1. Establish uses for end product and obtain commitments
2. Initiate necessary permits and approval procedures
3. Establish collection system requirements and procedures
4. Prepare detailed design of facility including
   - surface and drainage
   - receiving area layout

- chipping area layout
- windrow area layout
- storage/curing area layout
- utility hook-ups, if needed
- building/structures
- access roads
- fencing
- irrigation system, if needed

5. Prepare equipment specifications
6. Establish personnel requirements
7. Prepare operating plan
8. Develop public education program
   - about home composting
   - about participation in municipal collection system
   - about use of final product
9. Conduct detailed economic analysis

III. Construction and Operation

1. Procure equipment
2. Implement public education program
3. Make site improvements
4. Hire and train personnel
5. Begin operations
6. Maintain records
7. Evaluate the project regularly
8. Refine operational procedures

APPENDIX B

WINDROW TEMPERATURE DATA SHEET

Data collected by:________________________ Date__________ Time of Day________________

Weather information (sunny, rain, etc.)____

Wind direction (Northeast, South, etc.)____

Air temperature: °F ______ or °C_______ time of day_____________________________________

Site observation comments (windrow turned, water ponding, odor, etc.) _________________

____

____

____

Windrow moisture (hand-fist squeeze observation) - circle response

Needs moisture Satisfactory Excess

Windrow temperature measurement location	Temperature Observation, °F or °C Windrow Observation (See Sketch Below) A	B	C	D	E	F
1						
2						
3						
4						
5						

Windrow # 1

A B C D E F

2

A B C D E F

3

A B C D E F

4

A B C D E F

5

A B C D E F

Observation Location

APPENDIX C

TROUBLESHOOTING AT A GLANCE

PROBLEM	CAUSE	SOLUTION
Anaerobic odor	Excess moisture Windrow too large Temperature greater than 140°F Leaf compaction Surface ponding	Turn windrow Make windrow smaller Turn windrow Turn or reduce windrow size Eliminate ponding Apply odor masking agent
Low windrow temperature	Windrow too small Insufficient moisture Poor aeration	Combine windrows Add water while turning windrow Turn windrow
High windrow temperature	Windrow too large Leaf compaction	Reduce windrow size Turn windrow
Surface ponding	Depressions or ruts Inadequate slope design	Fill depressions and/or regrade Grade site to recommended slope
Vectors		
Rats	Presence of garbage (food, etc.)	Remove garbage, or use rat bait
Mosquitoes	Presence of stagnant water	Eliminate ponding
Pollution of surface waters	Leachate discharge	Treat leachate before it leaves site by passing it through soil, sand, or grass filter area Avoid surface runoff
Fires/spontaneous combustion	Excessive temperature Inadequate moisture Stray sparks, cigarettes, etc.	Make windrow smaller Add water Keep potential fire sources away from windrows If fires do start, break windrows apart and extinguish completely

Odor

Odor is the most prevalent problem at yard waste composting sites. Avoiding odor problems usually depends on avoiding prolonged anaerobic conditions. Under anaerobic conditions, volatile organic acids, alcohols, and sulfur compounds can be produced that alone or together can smell very unpleasant.

High nitrogen wastes also can result in odors. For example, too large a proportion of grass clippings, etc. can result in ammonia volatilization. Ammonia odors are most prevalent in high pH conditions and usually signify loss of nitrogen nutrients from the compost.

Making the windrow too large, especially when it is first formed, can lead to odors. Oxygen cannot readily or thoroughly penetrate an overly large windrow. An anaerobic core develops as decomposition slows and odor producing acid fermentation occurs.

It is sometimes possible to contain odors by leaving the offending materials undisturbed until oxygen has penetrated them sufficiently to destroy the odors. However, this may take several months or even years. Taking off 1-2 foot layers from the edges, as they become aerobic, may help speed the process. However, for most communities, a long wait is not practical. Because many of the anaerobic and odorous compounds are acidic in nature, powdered or a liquid slurry of limestone added to the surface of the windrow may help neutralize odors. However, lime will exacerbate ammonia odors. In this case, adding more high carbon materials will balance the C:N ratio and reduce ammonia odors.

If odors remain a concern, their off-site impact can be minimized. Windrows should be turned only when wind conditions are favorable, i.e., when the site is downwind of residences and other sensitive neighboring land uses. Higher wind speeds are preferable because they dilute any released odors faster than do calm conditions.

Leachate

The term "leachate" may not be the most appropriate term for the liquid that sometimes comes from yard waste compost windrows, because this liquid is relatively innocuous. The terms "leafate" or "runoff" have been suggested as a better description. Ideally, the composting process will evaporate most available moisture within a windrow, resulting in minimal excess liquids. These liquids should not differ greatly from those that occur during decomposition in a forest. However, because composting concentrates so much organic matter in a small space, certain precautions should be observed.

Ponded water is common where heavy equipment operates on soft surfaces. Odors can result because anaerobic conditions are likely to develop. Standing water also can serve as a mosquito breeding environment, and muddy conditions can interfere with operations on the site. Prevention, in the form of careful site regrading, is the best remedy. Windrows should run down slopes as opposed to across them. If ponding occurs and odors are released from the pools, adding pulverized limestone may help.

Pollution of surface waters is an additional concern. While leachate is generally not toxic, it may deplete the dissolved oxygen in the water. This can affect fish and other aquatic organisms. It may also lead to discoloration of the water.

In order to prevent pollution, leachate should not be allowed to enter surface waters without prior treatment. This treatment might consist of simple percolation down into or through the soil, or passage through a grass buffer strip constructed to intercept the horizontal flow. In passing through the soil or grass strip, the leachate is both physically filtered and biologically degraded to remove a substantial portion of the pollutants.

Inadequate Composting Rate

Inadequate composting rates can occur for a variety of causes. The most common is that the windrow is too dry. Windrows with wide, flat or concave tops and steep sides will maximize the collection and infiltration of precipitation. Water added initially, before or during windrow formation, and during combining and/or turnings will insure adequate moisture levels.

Composting also is slow when windrows are too large. Once acidic anaerobic conditions occur, the materials tend to be preserved rather than decomposed. Using smaller windrows will avoid this problem.

Other Issues

Other potential problems at yard waste composting facilities include: noise, dust, toxic materials, herbicides, and substances to which people may be allergic.

Noise may be a concern depending on the equipment used and the site location. Mufflers can be required for all equipment, however, they are expensive. Noise barriers also could be used to minimize neighborhood impact.

Litter can become a problem, especially if the yard waste is not properly separated. One suggestion is to plant vegetation on the perimeter of the site to act as a wind screen. If bags are handled at the site, perimeter fencing can prevent bags from blowing onto neighboring property.

Dust from the windrows can be minimized by proper wetting. Dust from roads and aisles may remain a problem unless they are paved, but should be no worse than at other unpaved sites.

Leaves and other yard waste may contain trace levels of certain heavy metals. Metals will not be degraded in the composting process. However, the concentration of metals in compost is usually very low and meets state and federal requirements for land utilization of wastes.

The DEC's criteria for Class I compost is its most stringent classification, and indicates that compost is suitable for public distribution as well as agricultural or horticultural use. Acceptable concentration levels for Class I compost, as well as results from analysis of leaf compost from the Croton Point Demonstration Facility in Westchester County and typical New York soils are indicated in the table below.

In every case the leaf compost falls well below DEC limits, and is comparable to the background levels found in typical soils. While quality control and the prevention of contaminants is important at a composting facility, these results indicate that yard waste compost is a safe and high quality product.

Table C.1 Heavy Metal Concentrations in Compost and Soil

Parameter	DEC Class I Compost (ppm dry weight)	Croton Leaf Compost (ppm dry weight)	Typical NY Soils (ppm dry weight)
Mercury	10	*	0.1
Cadmium	10	0.1	0.2
Nickel	200	10.1	17
Lead	250	31.7	13
Chromium - total	1000	10.5	59
Copper	1000	19.1	96
Zinc	2500	68.2	124
PCBs - total	1	*	*

* Data not available

APPENDIX D

COLLECTION AND PROCESSING EQUIPMENT

Equipment requirements for yard waste collection and processing vary substantially with the type and size of operation. Intermunicipal agreements among neighboring towns can provide economies of scale that may allow municipalities to buy equipment that is capital intensive. This appendix briefly discusses the major types of collection and composting equipment available and provides preliminary cost estimates

A. Leaf Collection Machines

Vacuum leaf collectors are designed to suck up leaves that have been raked into the street or onto the curbside median. The leaves are blown into tag-along units that are towed behind a truck. Fully equipped vacuum trucks come in various models, some with compaction capacity up to 32 yards per load. Many vacuums have manually operated intake hoses 7 to 18 inches in diameter. Some models include an internal shredding system. Their advantages are that they collect completely and clean the street. Some disadvantages are that they are slow, require a crew of several laborers, and will pick up stones and other contaminants.

A front-end loader is another efficient way of collecting leaves when leaf fall is heavy. A claw attachment to a front-end loader (costing about $10,000) can open to a spread of about 8 feet and scrape up leaves with two horizontal pincers without damaging an uncurbed shoulder of a street. A street sweeper, with a modified broom, can pick leaves for more efficient loading with a front-end loader. The front-end loader then picks them and deposits them in a truck. Because leaves are so light, dump trucks may be full, although weight is low. Compactor trucks avoid this problem, an advantage for long hauling distances. Two or more trucks may be needed to serve one loader crew. A leaf loader also sweeps leaves off the street, but is towed behind a packer or dump truck. As leaves are blown into a truck, they pass through a shredding device to reduce volume. Table D.1 provides 1989 prices for collection equipemnt.

B. Front-end Loaders

A front-end loader is the single essential piece of equipment for yard waste composting and the only equipment used by the majority of communities. For leaf composting, the loader needs to be available continuously for windrow building between mid-October and mid-December, thereafter only for turning. Both track loaders and wheel loaders may be used in composting operations. The track loader functions better in loose and muddy soils, is useful in rough site grading, and can move piles of dense materials. The wheel loader, however, is more versatile, more easily maneuvered, and causes less damage to road and ground surfaces.

Track and wheel front-end loaders come in various sizes with standard and optional accessories. They usually are equipped with diesel engines and are hydraulically powered, although models using gasoline and other fuels also are available. Bucket sizes range from 3/4 to 4 cubic yards and are dictated by engine size and intended use. Because compost is much less dense than gravel or soil, often a larger bucket can be used than is normal for a particular machine. A two part drop bucket may be useful in building vary large windrows. Prices for front-end loaders equipped with the basic accessories range from about $50,000 to $125,000.

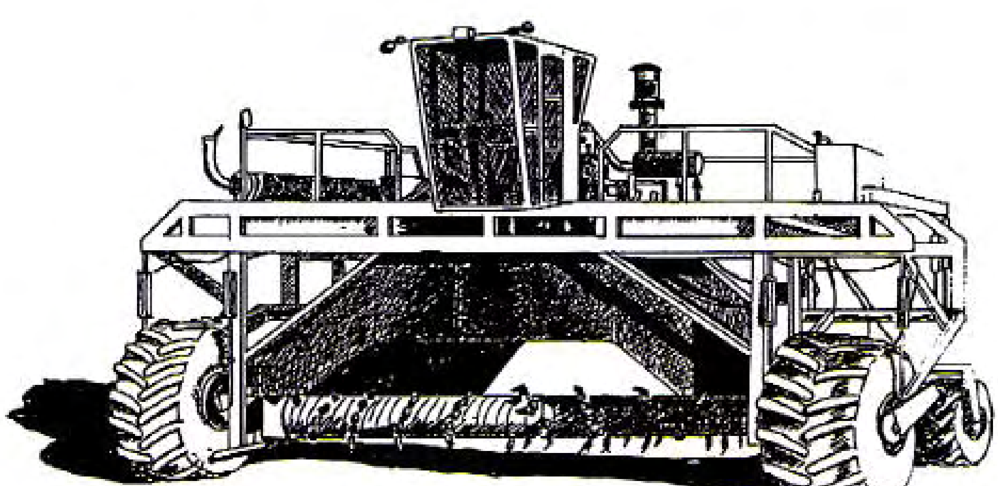
Table D.1 Leaf Collection Equipment and Approximate Prices in 1989

A.	Compactor trucks:		
	(1)	20 cu yd; 240 hp diesel; automatic transmission; single axle	$80,000
	(2)	25 cu yd; 270 hp diesel; automatic transmission; double axle	$95,000
B.	Vacuum leaf collectors:		
	(1)	tag-along; 18-inch intake; 16,000 cfm; gasoline engine	$9,000
	(2)	trailer mounted; belt driven; 12-inch intake; 12,000 cfm;	
		(a) with gasoline engine	$20,000
		(b) with diesel engine	$21,500
	(3)	trailer mounted; power-take-off and clutch connection; 18-inch intake; 24,000 cfm; diesel engine	$14,000
	(4)	trailer mounted; impeller on engine crankshaft; 18-inch intake; 22,000 cfm; gasoline engine	
		(a) 14 cu yd; dump box	$14,500
		(b) 20 cu yd; dump box	$16,000
C.	Catch basin cleaners:		
	(1)	complete unit including truck; 12-inch intake; 12,000 cfm; diesel engine on vacuum unit;	
		(a) 10 cu yd; capacity	$100,000
		(b) 16 cu yd; capacity	$120,000
D.	Mechanical claw		$10,000

C. Windrow Turners

Windrow turners are designed especially for windrow turning and aeration. Large units straddle the windrow and smaller units are side mounted on front-end loaders or tractors that are driven between windrows. As a large unit moves over the wastes, plow fenders gather the materials into a powerful belt-driven or hydraulically-driven drum. The metal teeth on the rotating drum shred and aerate the compost and are aligned so that materials are redeposited in a pyramid-shaped windrow. Some models can be connected to water lines so wastes can be irrigated as they are turned. Compost turners are not designed to accept brush and other woody vegetation unless those materials have been chipped. (See Appendix N.)

The large, self-contained turners can process about 2,000 to 4,000 cubic yards per hour and cost from $100,000 to $185,000. Tractor and loader-mounted units cost from $10,000 to $100,000 and are designed to turn smaller windrows. A major maintenance requirement of turners is replacement of the flails or teeth, which cost from $375 to $500 per set. If a compost turner is to be used, community officials may prefer to lease a turner or share the cost with one or more other composting projects.



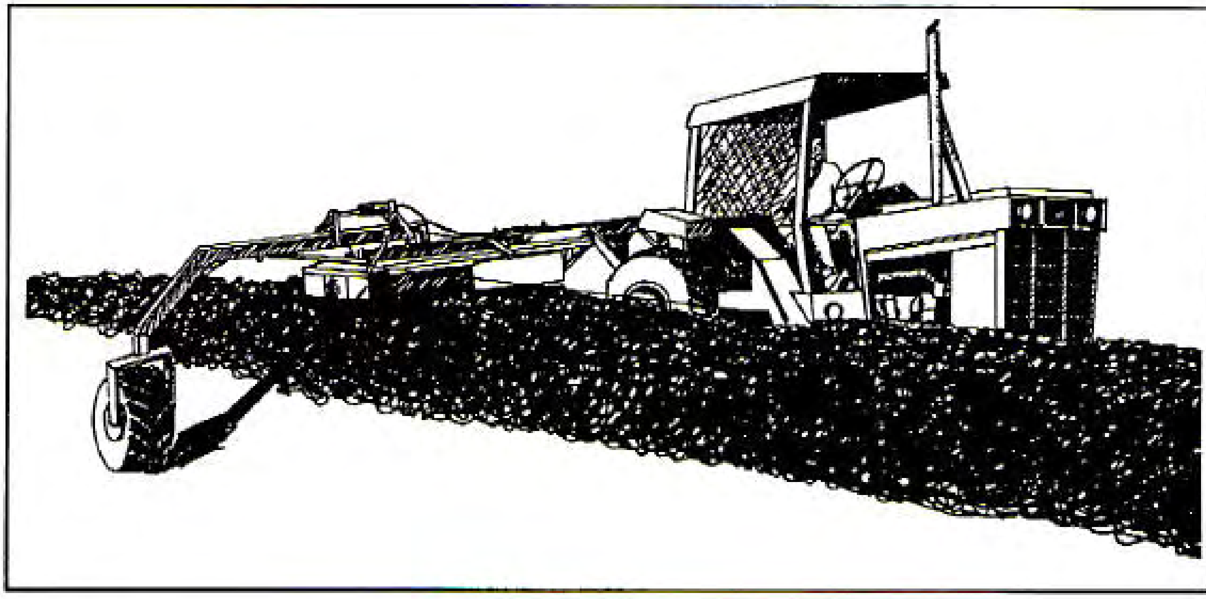


Table D.2 on page 85 provides some basic information for six brands of windrow turning equipment. Mention of a brand or model is not an endorsement of that product. An omission of a particular brand or model should not be viewed as a negative comment either.

D. Monitoring Equipment

Thermometers may be the only instruments needed to monitor composting operations. A thermometer with a three to four-foot stem and 0° - 200 °F or 0° - 100°C range is an esential item. They cost from $50 to $100 each. Temperature readings allow operators to determine the most appropriate time to turn the material. When the temperature rises above 140°F (60°C) or drops below 90°F (32°C), operators should turn and mix windrows.

A thermometer with a digital readout may be needed for automated aerated static pile composting. Such thermometers cost about $500 each, and additional instrumentation and computer or thermostatic controls can increase the cost. A simpler, but more labor intensive means of blower control, relies on manual temperature measurement and the use of automatic timers to control blower operation. This should be adequate for yard waste composting, where temperature and aeration are somewhat flexible.

Although optional, an oxygen analyzer is a useful tool for determining the aerobic quality of compost. Oxygen levels should remain above five percent to avoid odors caused by anaerobic decomposition. Because ammonia neutralizes the absorbing fluid in a number of analyzers, interference chemicals should be checked before purchasing an analyzer. Oxygen analyzers, similar to the one shown in Figure D.1, are available for about $250 each.

Other laboratory test equipment for pathogens, pH, moisture, carbon to nitrogen ratio, and nutrients is not essential for most yard waste compost operations. Some of these tests may be important for marketing the finished compost, but can be performed at outside laboratories specializing in soil analysis.

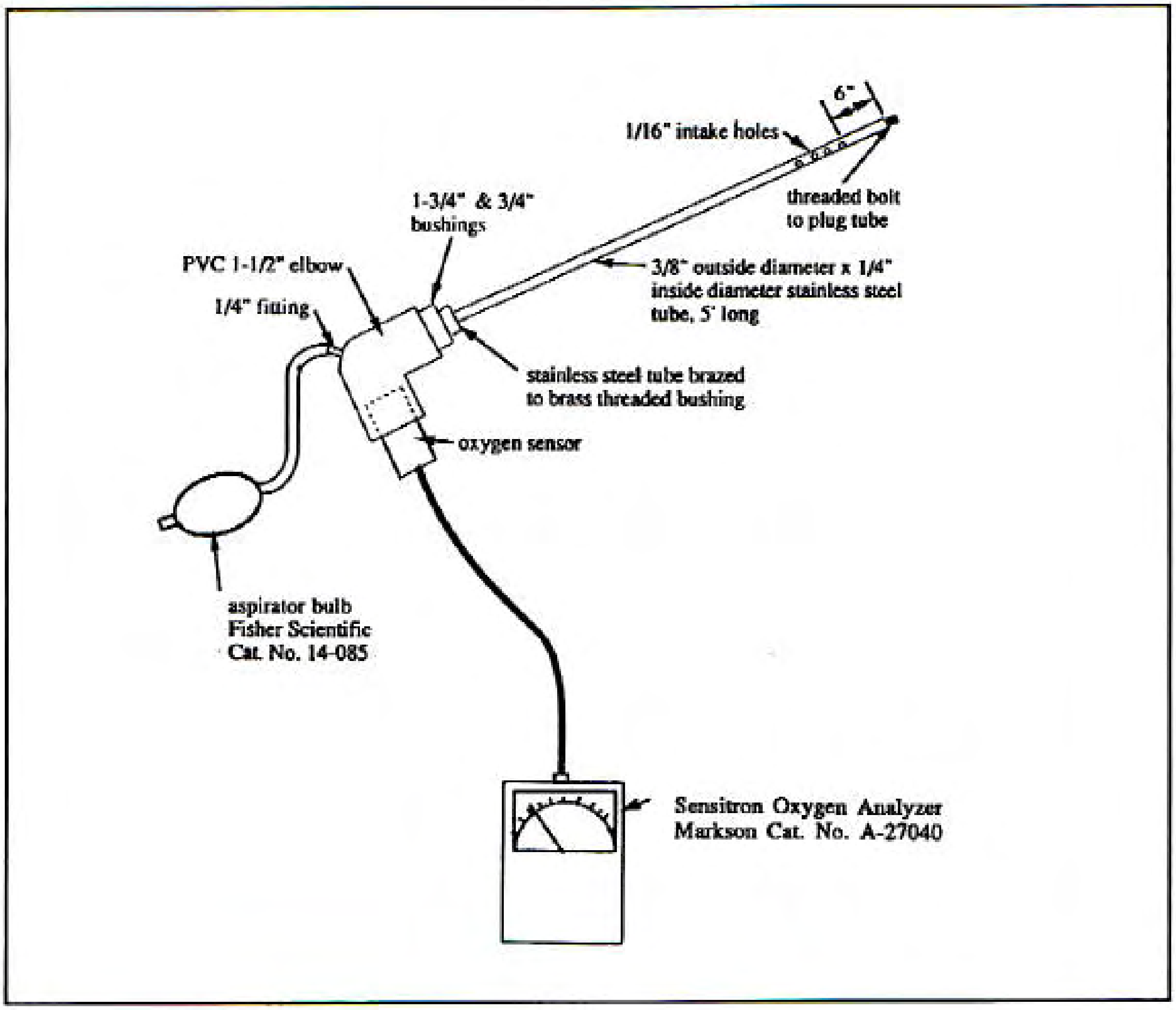


Figure D.1 Oxygen Analyzer for Compost

Table D.2 Windrow Turning Equipment and Approximate Prices in 1990 (A Partial List)

NAME	EQUIP. TYPE	SIZE/CAPACITY*	COST	COMMENT
Brown Bear	Model 200	115 hp 1,500 cu yd/hr 10' x 31" aerator head	$118,000	Auger moves compost to the side.
	Model 300	177 hp 3,000 cu yd/hr 10' x 3' aerator head	$140,000	"
	Model 400	225 hp 3,000 cu yd/hr 14' x 39" aerator head	$167,000	"
	Model 500	290 hp 4,000 cu yd/hr 12' x 4' aerator head	$195,000	"
Cobey Composting (Eagle Crusher Company)	Model 12A	225 hp 1000-2000 tons/hr 14' x 6' windrow	$135,000 to $185,000	Straddles windrow and drum lifts and turns compost
Resource Recovery Systems	K-W 614	300 hp 5,000 cu yd/hr 2000 ton/hr 14' x 6' windrow	$100,000	Straddles windrow and drum lifts and turns compost.
	hydraulically driven drum - optional		$ 50,000	
	K-W 616	300 or 440 hp 6000 cu yd/hr 2500 ton/hr 16' x 6' windrow	$125,000	
	K-W 718	440 hp 7500 cu yd/hr 3000 ton/hr 18' x 7' windrow	$160,000	
Scarab	Scarab 14	234 hp 2,000 tons/hr 14' x 6' windrow V-belt drive	$104,000	Straddles windrow and drum lifts and turns compost.
	Scarab 18	360 hp 3,000 tons/hr 18' x 7' (hydraulically driven)	$174,000	"

Table D.2 Windrow Turning Equipment and Approximate Prices in 1990 (A Partial List)

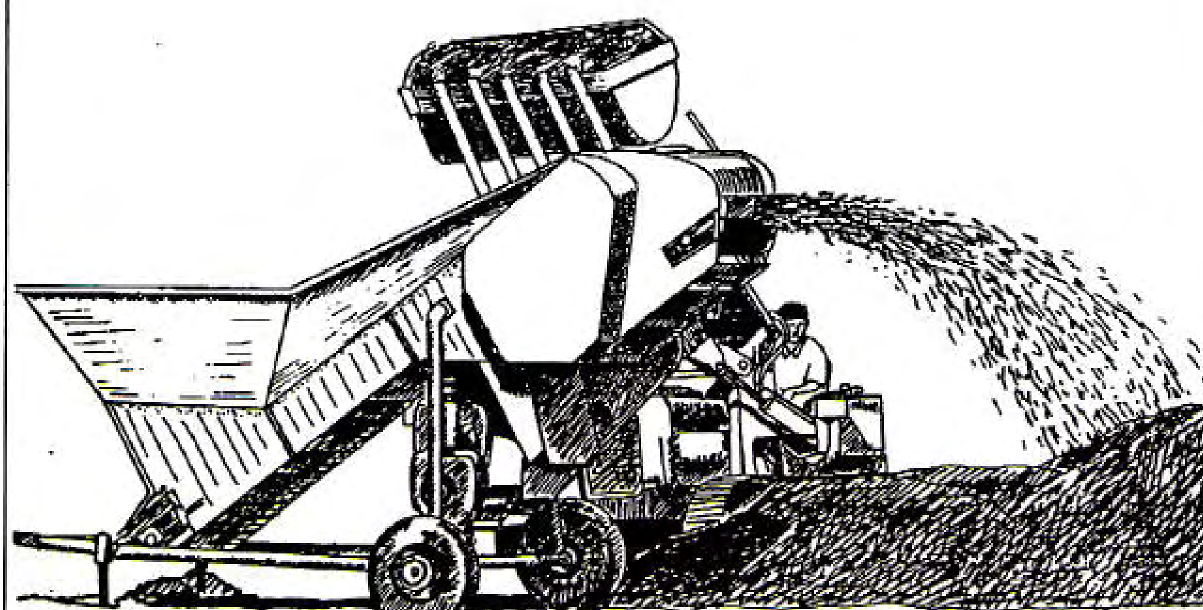
NAME	EQUIP. TYPE	SIZE/CAPACITY*	COST	COMMENT
Scat	482B	65 hp 3,000 cu yd/hr 2,000 tons/hr 18' x 6' windrow	$55,000	2-pass type elevating face, needs 60 hp tractor to pull.
	483B	85 hp 4,000 cu yd/hr 3,000 tons/hr 20' x 9' windrow	$75,000	2-pass type elevating face, needs 80-100 hp tractor to tow.
	483I	107 hp 4,000 cu yd/hr 3,000 tons/hr 20' x 9' windrow	$155,000	2-pass type self-propelled.
	Larger or custom units available			
Wildcat	FX 700	300 tons/hr 14' x 4' windrow	$13,400	Needs 60-120 hp tractor with hydrostatic drive or creeper gear transmission.
	C700	400 tons/hr 14' x 4' windrow	$19,500	Needs 90-140 hp with hydrostatic drive.
	CX700M	117 hp 800 tons/hr. 14' x 5' windrow	$22,000	Self-powered; mounted on 2 yd. capacity front-end loader.
	CX750ME	177 hp 14' x 5' windrow 1,100 tons/hr	$70,000	Self-powered; mounted on 3 yd. capacity front-end loader.
	M700E Special	325 hp 2,600 tons/hr 18' x 71/2' tall	$100,000	Self-powered; mounted on 4 yd. capacity front-end loader.

*Capacity as reported by the manufacturer. Actual processing quantities will vary widely, depending on the type and size of material, moisture content, etc.

E. Grinding and Shredding Equipment

High torque shear shredders, hammermills and tub grinders are the three categories of grinding and shredding equipment used for yard waste composting.

A shear shredder is a stationary or trailer-mounted machine that reduces the size of material through the action of knives. Material is loaded into a receiving hopper with either a hopper or hand-fed conveyor. The conveyor drops the materials onto a belt that undergoes a continuous raking action to shred and aerate the load. By the use of adjustable, variable sweep fingers, oversized pieces are forced back for further shredding while unshreddable material, such as sticks, stones, metal, and glass are rejected and discharged through a trash chute. Shredders usually can only handle material less than four to six inches in diameter, and may require a grate over the hopper to exclude oversize items. Shredders can process from 25 to 250 cubic yards per hour and cost from $15,000 to over $100,000 depending on size and options selected. A shredder may be operated by a single operator, or by shredder and loader operators. A municipality may want to consider renting a shredder because it will only be required for several weeks each year, or sharing a shredder with other communities.



Material dropped into a hammermill is size-reduced by free swinging metal hammers mounted on a spinning shaft, which pound material until it is small enough to drop through discharge openings.

Grinders are designed to crush wood and brush as large as four inches in diameter. They are characterized by a rotating tub-type intake system. The rotation moves materials across a fixed floor containing hammermills that shear the material. As material is ground, it is forced through a screen and then conveyed into standing piles or into a transfer vehicle. Tub grinders are loaded with a bucket loader or a conveyor belt.

Tub grinders are available in different models that have significantly different capabilities. Big, heavy-duty grinders are suitable for grinding large amounts of dry wood and brush. Portable units are available with diesel or gasoline engines ranging from about 300 to 500 horsepower. Stationary units use diesel or electric engines. Tub grinders can process from 10 to 20 tons per hour depending on factors such as type of waste, screen size used, and waste moisture content. Proper mixing of wastes and use of varying screen sizes will reduce jamming and increase throughput efficiency. A complete set of screen sizes (about three quarters of an inch to five inches) should be obtained with the grinder. A tub grinder requires one person to operate it and a second person to load materials into the machine.

Grinders range from $60,000 to $140,000 and require regular maintenance, including rotation and replacement of the hammers. A new set of 96 hammers costs approximately $900 to $1,400 and takes two to three hours to install. Hammers typically need to be rotated after about 50 hours of operation and replaced after 140 to 240 hours of operation, but may wear much quicker if the steel surfaces are poor quality or there is a lot of abrasive material in the woody debris.

The type of material, density of material, rate of feed, type of feed, output volume requirements, shred size and consistency all influence the design for a specific application. Table D.3 lists a number of manufacturers of grinding and shredding equipment. Mention of a brand or model is not an endorsement of that product. An omission of a particular brand or model should not be viewed as a negative comment either.

APPENDIX I

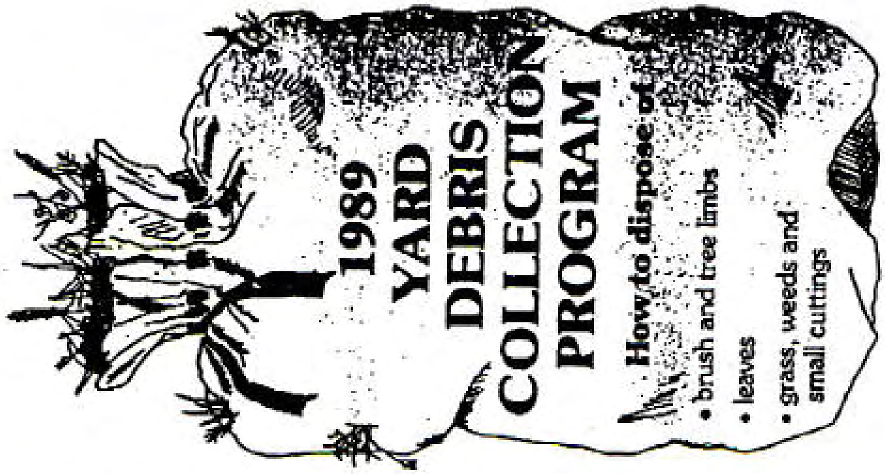
YARD WASTE DELIVERY LOG

_______ Day of Week _______ Month _______ Date _______ Year

	Time	Permit #	C.Y.	Woody	Leafy	Mixed		Time	Permit #	C.Y.	Woody	Leafy	Mixed
1							39						
2							40						
3							41						
4							42						
5							43						
6							44						
7							45						
8							46						
9							47						
10							48						
11							49						
12							50						
13							51						
14							52						
15							53						
16							54						
17							55						
18							56						
19							57						
20							58						
21							59						
22							60						
23							61						
24							62						
25							63						
26							64						
27							65						
28							66						
29							67						
30							68						
31							69						
32							70						
33													
34									TOTAL				
35							NOTES:						
36													
37													
38													

APPENDIX J

YARD DEBRIS COLLECTION PROGRAM PAMPHLET



TOWN OF PITTSFORD

Town Of Pittsford
11 So. Main Street
Pittsford, N.Y. 14534

BULK RATE
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RESIDENT

PITTSFORD NY

NEW INFORMATION

1989 YARD DEBRIS COLLECTION

2/89

Dear Friend,

Enclosed is information regarding our yard debris collection program for 1989. We thank you all for your cooperation with our 1988 program. An effort has been made to improve service to all residents for the coming year.

Since the State and County continue to address problems of solid waste disposal, we have designed a flexible program for the coming year which will enable us to take advantage of any new regional developments. Because of the governor's mandated reduction of the waste stream, complete recycling of yard debris remains our goal. Please feel free to call me if you have any questions after reading this brochure.

Sincerely,

Margaret M. Freeman
Supervisor
Town of Pittsford

YARD DEBRIS COLLECTION PROGRAM

BRUSH AND TREE LIMBS

What Will Be Collected?

All brush and tree limbs which are greater than 3 feet in length and no more than 8 inches in diameter placed at the curb.

Who Collects It?

Town of Pittsford Highway Dept.

When Will It Be Collected?

On a twice a month schedule, the same as last year, during the period of April 1 to November 30.

How To Get It Ready For Collection?

✔ Do place parallel and behind curb in piles separate from other materials.

✔ Do reduce all material to 8 foot lengths.

✔ Do coordinate yard work with pick up schedule.

⃠ Don't mix other yard materials with brush and limbs.

⃠ Don't create a traffic hazard by placing brush and limbs in roadway.

Questions About Collection?
Call 248 6270

LEAVES

What Will Be Collected?

All **loose** leaves placed at the curb.

Who Collects It?

Town of Pittsford Highway Dept.

When Will It Be Collected?

On a twice a month schedule, the same as last year until November 30.

How To Get It Ready For Collection?

✔ Do place leaves in piles behind the curb.

✔ Do consolidate small piles.

✔ Do coordinate yard work with pick up schedule.

⃠ Don't mix other yard materials with leaves.

⃠ Don't create a traffic hazard by placing leaves in roadway.

Questions About Collection?
Call 248-6270.

— NEW THIS YEAR —

GRASS, WEEDS AND SMALL CUTTINGS

What Will Be Collected?

Grass, weeds and small cuttings (**less** than 3 feet in length) placed at the curb, which are bagged, containerized or bundled.

Who Collects It?

Town of Pittsford Highway Dept.

When Will It Be Collected?

A weekly schedule, during the period of April 1st to November 30th.

How To Get It Ready For Collection?

✔ Do place bags, containers or bundles behind the curb.

✔ Do bring your bags, containers or bundles to the **dedicated road** if you live on a private drive.

⃠ Don't put loose debris at curb.

⃠ Don't create a traffic hazzard by placing bags, containers or bundles in roadway.

⃠ Don't exceed 50 pounds per bag or container.

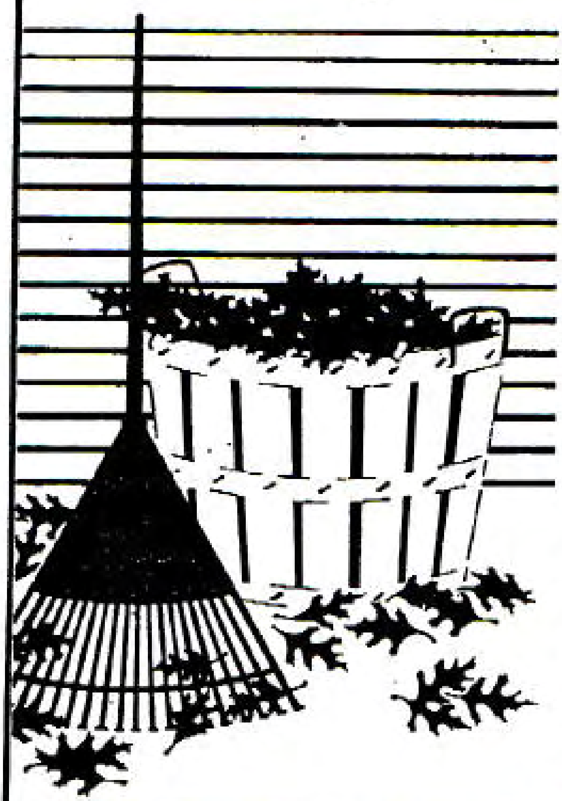
Questions About Collection?
Call 248-6270.

SAVE THESE IMPORTANT DIRECTIONS

APPENDIX K

COLLECTION ADVERTISEMENT

Composting... feed your garden, not the landfill



Composting is recycling in its most natural form. Composted leaves and yard wastes (like grass clippings) provide you with an excellent soil builder for your vegetables, flower beds and potted plants. Instead of having this high volume organic material hauled to the dump by city collection, recycle it by composting. You'll help save vast amounts of space in our shrinking landfill, and provide a wonderful addition to your garden.

For more information about how you can start composting, call Ithaca Recycles at 273-3470, or your Cooperative Extension office.

A special collection of materials appropriate for compost will be made in the City of Ithaca April 24-28. Be sure to have your leaves, clippings and small brush ready for pick-up. Call DPW at 272-1718 for more information.

This ad sponsored by

Ithaca Recycles

APPENDIX L

YARD WASTE MANAGEMENT SITE ASSESSMENT FORM

Site Name________________________________ Date of Inspection_________

Site Location Description____________________ Inspected by:____________

This form is designed for use in the field, to obtain an objective assessment of the proposed site. The various "factors" considered at each site receive a rating from 1 to 5, with 1 being least desirable and 5 being most desirable.

FACTORS	RATING	COMMENT
1. Site Preparation Costs		
a) compost area development	______	______
b) access road construction	______	______
c) security set-up	______	______
2. Site Characteristics		
a) soil characteristics	______	______
b) proximity to water; streams, lakes	______	______
c) slope and topography	______	______
d) acreage	______	______
e) drainage	______	______
3. Access by Public Roads	______	______
4. Infrastructure		
a) water	______	______
b) existing access road	______	______
c) storage	______	______
d) telephone	______	______
e) electric	______	______
f) scale	______	______
5. Proximity to Homes	______	______
6. Proximity to Town in Need	______	______
7. Regional Site Potential	______	______

FACTORS	RATING	COMMENT
8. Land Ownership	______	______________
9. Environmental Impact		
a) tree removal	______	______________
b) habitat disturbance	______	______________
10. Impact on Current Use		
a) visual	______	______________
b) physical	______	______________
11. Impact on Future Use		
a) visual	______	______________
b) physical	______	______________
12. DEC Criteria (minimum distances)		
a) property line, 50 ft.	______	______________
b) residence or business, 200 ft.	______	______________
c) potable water well, 200 ft.	______	______________
d) surface water supply, 200 ft.	______	______________
e) drainage swale, 25 ft.	______	______________
f) water table, 24 inches	______	______________
TOTAL RATING	______	

General comments relative to suitability of site to serve as a municipal composting facility:

____

____

APPENDIX M

WORKSHEET FOR CALCULATING THE AREA NEEDED FOR A LEAF COMPOSTING SITE

(assuming an 18 month compost cycle and a 50% volume reduction in the first year)

1. How many single family dwelling units in collected area? _______
A

2. Assume each household generates 200 pounds of leaves (about 0.8 yd^3 loosely packed). Then the volume of leaves generated is:

_____ x 0.8 yd^3 = _____ yd^3 total volume leaves
A B

3. What percentage of the total volume will be collected? Talk to municipal collection crews or private haulers to find out the percentage of households that set out bags of leaves. Consider the impact of a mandatory source separation ordinance or a home composting information campaign, if either is planned.

_____ % leaves collected
C

4. _____ x _____ = _____ yd^3 leaves to be composted annually
B C D

5. How much volume is left after one year?
How long will compost material be on site?
If you are turning windrows twice a year and adding little or no water then assume an 18 month retention time. Also assume that the first year's volume of yard waste is reduced by 50% after one year on site.

_____ yd^3 x 0.5 = _____ yd^3 yard wastes remaining after one year.
D E

6. To calculate the potential maximum volume on site at any time, add the second year's incoming volume.

_____ yd^3 + _____ yd^3 = _____ yd^3 on site second year
D E F

7. Assume one acre of land is needed to compost 3,500 yd^3 of leaves.

_____ yd^3 + 3,500 yd^3/acre = _____ acres needed

F

The value of F will be the range of acreage needed to compost 3,500 yd^3. A buffer area to surround the compost pad will need to be added to this acreage.

APPENDIX X

YARD WASTE MANAGEMENT COSTS: BUDGET WORKSHEET FOR MUNICIPALITIES

Note: This worksheet excludes most collection costs, which are generally assumed similar whether yard waste is composted, landfilled, or incinerated. Your own experience may show otherwise. Expect that some of the following costs equal zero.

I. ANNUAL OPERATING COSTS

LABOR

Calculation: For each entry, multiply the number of hours worked in a day by the number of days worked during the year by the hourly labor cost (including benefits, and possible overtime) by the number of included workers. This equals the annual cost. In symbols, the calculation is:

(_____ hours worked/day) x (_____days worked/year) x ($_____/hour)

x (_____workers) = $_____/year

1.	Monitoring site and windrows	$_____
2.	Emptying bags of yard waste	$_____
3.	Wetting yard waste	$_____
4.	Forming and turning windrows	$_____
5.	Screening and shredding compost	$_____
6.	Moving compost to storage	$_____
7.	Repairing equipment	$_____
8.	Maintaining site	$_____
9.	Allocated cost of administration and training personnel	$_____
10.	**TOTAL ANNUAL LABOR COSTS:** **(Add lines 1-9)**	**$_____**

EQUIPMENT (OPERATING)

These calculations are for cash expenses for operating costs, maintenance costs and rental costs only; capital expenses are recorded in a later section. Cash expenses include: fuel, repairs, spare parts, and rentals. For rentals, calculate the actual cash expense you incur during one year.

11.	Front end loaders (windrow forming, turning)	$_____
12.	Dump truck (moving yard waste at site)	$_____
13.	Screen/Shredder	$_____
14.	Water truck	$_____
15.	Specialized compost turner	$_____
16.	Other equipment	$_____
17.	Maintenance of roads, fences, drainage and water systems, and buildings.	$_____
18.	**TOTAL ANNUAL CASH EXPENSES FOR EQUIPMENT: (Add lines 11-17)**	**$_____**

ADDITIONAL OPERATING COSTS

19.	Permits and fees	$_____
20.	Fuel and utilities	$_____
21.	Monitoring equipment, tests, and other supplies	$_____
22.	Hauling rejects and contaminated yard waste to disposal facility	$_____
23.	Special collection bags provided to residents	$_____
24.	Public education and promotion	$_____
25.	Marketing and distribution of finished products	$_____
26.	Non-labor overhead costs	$_____
27.	Other additional operating costs	$_____
28.	**TOTAL ANNUAL ADDITIONAL OPERATING COSTS: (Add lines 19-27)**	**$___**
29.	**TOTAL ANNUAL OPERATIING COSTS: (Add lines 10, 18, 28)**	**$____**

II. ANNUAL CAPITAL COSTS

For each entry, convert the initial capital cost to an annual cost by including an allowance for annual depreciation over the service life and annual interest on investment. This allowance is called a capital recovery factor (CRF): see Table X1.

SITE PURCHASE, PREPARATION, AND OTHER START-UP COSTS

30. Land purchased for composting site and buffer zone
    (**Not current value of underused land already owned)
    ($______) x (______ CRF) $_____
31. Land leased for composting site and buffer zone $_____
32. Site grading, drainage system, water system, roads
    ($______) x (______ CRF) $_____
33. Fence, gate, gatehouse, signs, scale, storage shed, thermometers
    ($______) x (______ CRF) $_____
34. Engineering fees for site design and permit application $_____
    ($______) x (______ CRF) $_____

35. **TOTAL ANNUAL LAND AND LAND IMPROVEMENT COSTS:**
    (Add lines 30-34) $_____

EQUIPMENT (CAPITAL)

These calculations are for capital expenses only; operating expenses were recorded in an earlier section.

36. Front end loaders (windrow forming, turning)
    ($______) x (______% used for composting) x (_____CRF) $_____
37. Dump truck (moving yard waste at site)
    ($______) x (______% used for composting) x (_____CRF) $_____
38. Screen/Shredder
    ($______) x (______% used for composting) x (_____CRF) $_____
39. Water truck
    ($______) x (______% used for composting) x (_____CRF) $_____
40. Specialized compost turner
    ($______) x (______% used for composting) x (_____CRF) $_____
41. Other equipment
    ($______) x (______% used for composting) x (_____CRF) $_____

42. Maintenance of roads, fences, drainage and water systems and buildings $____

43. **TOTAL ANNUAL CAPITAL COST FOR EQUIPMENT:**
(Add lines 36-42) **$____**

44. **TOTAL ANNUAL CAPITAL COSTS:**
(Add lines 29, 43) **$____**

45. **TOTAL COMPOSTING COSTS PER TON:**
$____ Value for Line 44 divided by
_____ Annual tons of yard waste composted [1] **$____**

(1) Estimates of leaf weight (pounds/cubic yard): loose, 250; vacuumed, 350; compacted, 450. Actual values will vary with moisture content.

Table X.1 Capital Recovery Factor Values[1]				
Years of Service	Interest Rates			
Rates	7	8	9	10
1	1.0700	1.0800	1.0900	1.1000
2	.5531	.5608	.5685	.5762
3	.3811	.3880	.3951	.4021
4	.2952	.3019	.3087	.3155
5	.2439	.2505	.2571	.2638
6	.2098	.2163	.2229	.2296
7	.1855	.1921	.1987	.2054
8	.1675	.1740	.1807	.1874
9	.1535	.1601	.1668	.1736
10	.1424	.1490	.1558	.1627

[1]The formula for computing capital recovery factors not presented here is as follows:

where: i = annual interest or discount rate

n = number of years over which item is depreciated (expected service life)

$$CRF = \frac{i\,(1 + i)n}{(1 + i)n - 1}$$

Note: This is only one of numerous methods of calculating annual depreciation and interest on investment. If an allowance is to be made for salvage, value straight line depreciation and average annual interest on investment can be calculated as follows:

annual depreciation = (c - s)/n

annual interest = i(c + s)/2

where: c = initial cost

s = salvage value

n = service life in years

i = annual interest rate

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